Airtight storage of grain in silage bags

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<u>Cover</u>: 80.000 t grain in silage bags, agrarian holding in Russia

Content Page

1. Intro

Grain – should it be sold straight-away or should it be stored firstly? In case it should be stored, the question arises, how should it be stored? On the own farm or externally? For an in-house usage, grain is either used as feed or as energy feedstock in biogas plants. How should home-grown grain be stored, as wet or dry feed, as whole or milled corn?

Such questions arise more and more since the grain markets have changed continuously in the last few years – prices on raw material markets are increasingly not calculable anymore, however not only by reason of extreme weather. Due to price volatilities on the so called volatile grain market temporary storage capacities for grain and also demands on flexibility become much more important.

The foremost rule to avoid deterioration in granaries is the protection against humidity and contamination. Moreover, traceability is provided by the EU. Currently conventional grain storage causes investment costs of 100 to 250 EURO/t of grain, depending on the plant size, while costs for a six-months storage can be estimated around 20 EURO per ton.

Farms with livestock can save drying costs due to the conservation of wet grain und high-moisture corn. Especially the grain harvest in 2010 revealed what it means to have only short time available for combine harvesting and problems with the outgrowth of grain. Thus, an early harvest of wet grain offers advantages. Practical experiments prove that there are barely differences between feeding, milk yield or animal health of ensilaged and dried grain. So, why keep on drying?

More than 18 years ago the technology of storing materials in silage bags was reintroduced in Germany. Since then, discussions about this proceeding are increasing continuously. Reasons for this is the relatively easy labour management, the little fermentation losses, the high flexibility of this proceeding and the high fodder hygiene in the airtight silage bag system. Finally, it is not only about to keep the investment risk on a low level, but also the risk of deterioration.

Different properties of organic base material and diverse requirements on the performance in the harvest respectively on further processing have led to the fact that meanwhile there are different types of silo presses (with rotor, auger, roller mill etc.), which are also used for storing grain in silage bags.

This paper is about to illustrate the conservation principle of airtight storage of grain in silage bags, the technology, the costs and finally to give recommendations for usage. In the end some practical examples will be given.

2. Storability of grain

The initial quality of freshly harvested grain can only be sustained, but not improved (MAIWALD, 2001). Microorganisms (yeast, moulds and bacteria) and grain pests can cause losses in quality. The microbial activity in the granary can be influenced by the grain moisture content, the storage temperature, the pH-content and the ambient concentration of CO2. Under aerobic conditions the increasing storage temperature and moisture can reduce the possible storage period (tab. 1). In case the moisture content amounts more than 14%, storing without conservation measurements leads to an increase of moisture and contamination of moulds due to a self-heating process caused by the metabolic activity of microorganisms (SPIEKERS, NUSSBAUM, POTTHAST, 2009).

Tab. 1: Maximal storage period of grain in days (von KEISER, 2005)

Moisture (%)	**Storage period by given storage temperatures (°C)**					
	5	**10**	**15**	**20**	**25**	**30**
14	420	270	160	100	58	30
15	340	200	100	57	30	16
16	260	130	53	30	17	8
17	190	76	31	21	11	4
18	132	42	22	15	6	2

Deficiencies in hygienic quality arise not only during the storage (WEIß et al., 2005). Hence, toxins can result from fungal attacks on the field or in the granary. Outdoor moulds accumulate toxins already before harvesting. In poor years the grain is already contaminated by these toxins. However, indoor moulds occur only due to improper storage. Quality losses can be caused by grains pests as well (e.g. grain weevils).

To avoid losses and deterioration during the storage, the following measurements are indicated: dehydration, cooling, increase of acidity (silage) or airtight storage.

Conservation and storage are closely connected. In 1980 the airtight storage of grain was almost exclusively described as conservation in overhead hoppers (von KEISER, RKL-Schrift 1980). A low-cost solution was represented by butyl sacks whose production was stopped because of problems while draining and such caused by rodents. At that time airtight storing was already perceived as the only method, which requires no energy for conservation, even at increasing moisture contents. Freshly harvested wet but also dry grain was filled in silos and closed hermetically. The costs were even then evaluated positively in terms of increasing energy costs.

All types of grain can be stored airtightly and independently from the moisture content (von KEISER, 1980). In consequence of residual respiration activities of the threshed material a carbon-dioxide atmosphere results which prevents the development of micro-organisms and grain respiration. The process' intensity depends on the moisture content of grain. Under airtight conditions and increasing moisture content lactic acid bacteria become active and support the conservation process (tab. 2).

tab. 2: Grain after 50 days of airtight storage at different moisture content (MEIERING, RIEMANN, THYSELIUS, 1965)

Parameter	**Unit**	**Moisture content (%)**			
		15	**20**	**25**	**30**
Lactic acid content in grain	%	-	0,2	0,4	0,8
Acetic acid content in grain	%	-	0,1	0,15	0,25
Butyric acid content in grain	%	0	0	0	0
Content of carbon dioxide in the silo	Vol.-%	2,5	25	80	95
Content of oxygen in the silo	Vol.-%	5	0	0	0

For several years the silage bag technology is offered to store grain, oilseeds and pulse crop airtightly. This flexible method provides the opportunity to store wet and dry grain, either milled or not, in plastic bags. The intended usage of grain determines all technical aspects (fig. 1). Grain for consumption requires a moisture content of ≤14% for commercialisation meanwhile grain used for in-house bioethanol, biogas or feed can be stored even with a higher moisture content airtightly in the silage bag. This technology will be presented subsequently.

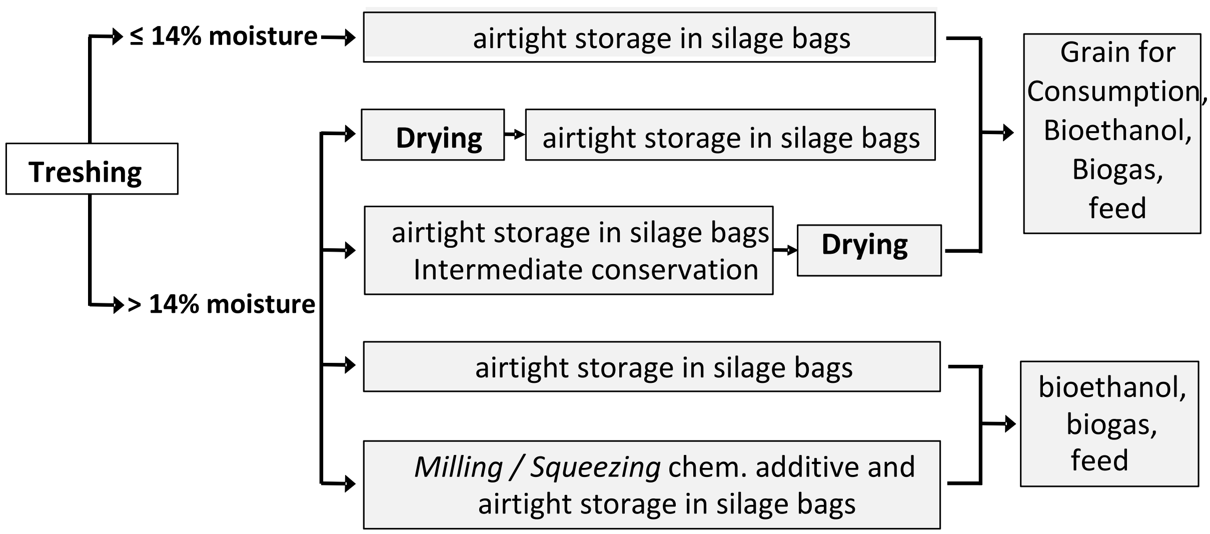

Fig. 1: Several alternatives of conservation / storage in silage

3. Grain in silage bags – technical aspects

3.1 Developments in Germany

Silo presses were already produced in 1968 by the company Eberhardt in Ulm. Meanwhile this method was know for an excellent silage quality due to the early and complete exclusion of air, the press was displaced by other silage methods as a result of a lack of performance and higher labour input. By exporting to the United States in the mid 70's the technology could be advanced and aligned to the modern harvesting chain. After the fall of the iron curtain the first silo press was imported to Eastern Germany. Since 1998, the machines are built again in Germany and exported to over 20 countries (international term BAGGER: to bag, to fill bags).

Meanwhile the developers of the Eberhardt-press concentrated on grass and maize, the range of substrates pressed in silage bags has extended enormously in the recent years - not at least by using agricultural products as feedstock and new industrial by-products (press pulp, brewer grains, marc, gluten etc.) (WEBER, 2006, WEBER, 2009).

According to different requirements silo presses are offered in various designs (for crop containing crude fibre or free-flowing bulk-material, with or without a crushing unit etc.) (tab.3). What they all have in common is the storage / conservation in a polyethylene bag.

Table 3: Different designs of silo presses

Components of the silo press	**Used for…**	**Performance**
Feed table, rotor; with grid and/or anchor	Roughage (grass, silage maize, lucernes, whole-crop silage), **grain**, by-products (Pressed pulp, Brewer grains) etc.	until 180 t/h
Hopper and auger	Free-flowing bulk-material, **grain**, maize, fertilizer, road-salt, industrial by-products	until 360 t/h
Hopper and push plate	Composting, organic residual material, Sugar beets	until 140 t/h
Hopper, roller mill and auger	**grain (wet and dry), grain corn,** sugar beets, industrial by-products	until 40 t/h
Truck with tunnel	Brewer Grains	

For storing grain mainly rotor machines, Farm Bagger and Grinder Bagger are used, which will be described in detail next.

3.2 Rotor machines – not only for substrates containing crude fibre

Rotor machines are generally recommended for ensiling roughage in silage bags. A rotor, which presses the silage containing crude fibre into the bag, generates a compression pressure over the entire width of the bag. This machine is used also for the conservation of pressed pulp. Besides, the storage of grain is possible. Classical rotor machines are offered with a grid. A grid at the end of the bag, which is connected with the machine by cable drums, provides a pressure build-up while filling the crop by means of a rotor into the bag continuously (fig. 3).

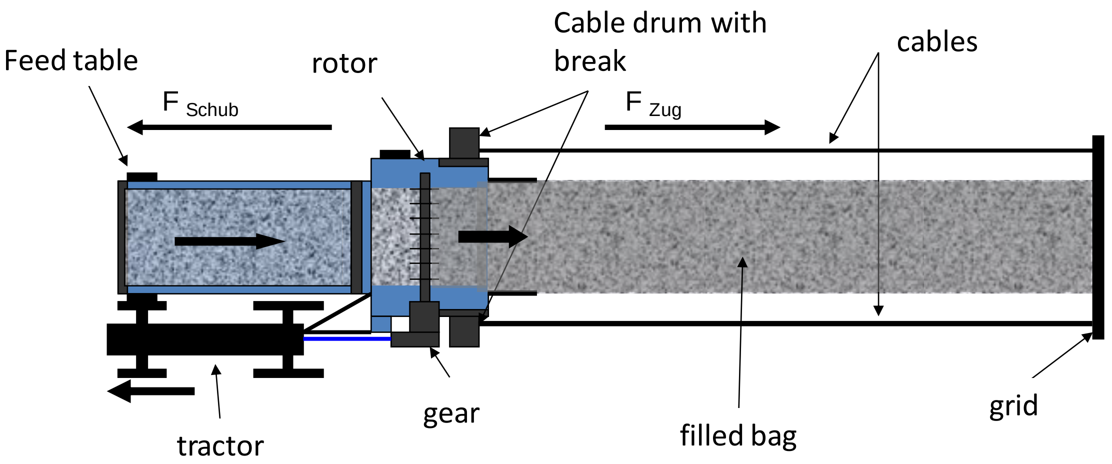

Fig. 3: Functional scheme of a silo press with rotor (MAACK, 2009)

In order to fill the rotor machine, end-dump trucks and self-loading trailers are used for harvesting crop. To avoid a standstill of the silo press, an integrated transport chain must be ensured.

The average performance of common machine types is about 100 t/h – especially for biogas plants with higher capacities there are new silo presses (with anchor) available with a performance up to 180 t/h. Rotor machines using the anchor system do not have a grid and work rather with one to two anchors (depending on the bag diameter). First they were dragged into the bag by the flow of goods. The length of the rope, which fixes the anchor, determines the compressing pressure. At the bag’s end the anchor has to be pulled in.

When not using the grid and the cable drum bag lengths of up to 150 m are possible. With a diameter of 3.60 m quantities of 1.000 t per bag can be achieved. In order to use anchor machines also the performance increases, since the setup time for changing the bag could be halved because there is no need to change the grid as well. Therefore the available bag diameters are between 1.50 m up to 3.60 m with bag lengths of 30 m up to 150 m.

This technology is suitable for conserving and storing maize products (whole-plant corn, CCM, grain corn, milled or not), grain and pressed pulp. Besides pre-wilted silages such as field grass, lucernes, clover and meadow grass can be filled into the bag by dint of the rotor machine.


Fig. 4: Rotor machine, also with adapter for free-flowing bulk-material, here wet maize

For storing grain the rotor machine can be equipped with a special adapter (Fig. 4). In this case the filling can be done by means of a grain wagon

3.3 FARM BAGGER for free-flowing bulk-material

Fig. 2: Farm Bagger and storage of grain in silage bags

The Farm Bagger allows storing grains and other free-flowing bulk-materials (e.g. fertilizer, road-salt) in silage bags. The tractor driven machine is filled by dint of a hopper. Furthermore, the grain falls on an auger, which presses the grain into the bag (fig. 2) – but first motor-driven machines are recently available.

The compression in the bag is controlled manually via a continuously adjustable brake system. The machines operator controls the film stretching (see printed stretching strips on the bag, target: maximal stretching by 10%) and adjusts the braking pressure of the machine accordingly. This fundamental principle of press pressure regulation applies to all types of silo presses.

The volume of a bag with a diameter of 2.70 m respectively 3.0 m is about 3.8 t respectively 4.5 t of grain per running meter. Therefore a (nominal) bag length of 80 m (filling length about 83 m) represents a storage capacity of up to 375 t of grain (latterly also 150 m bag length with nearly 700 t of grain). Of course, the bag can be cut at any length and adjusted to the operating conditions. After filling, the bag will be closed hermetically and covered with a bird net.

Freshly harvested grain can be processed contemporaneously to combine harvesting. According to measurements taken by the institute for agricultural engineering of the Hungarian Ministry of Agriculture in Gödöllö (2008) the Farm Bagger's average technical performance is about 360 t/h (tab.4). The technological performance of the Farm Bagger depends on the performance of the filling system. In this connection the crucial factor is the transportation logistic.

The following options for filling are available:

- Grain wagon (> 200 t/h),
- Front loader and hopper (100 t/h),
- Conveyor (even for heavy bulk-material, e.g. road salt) (60-100 t/h),
- Auger (60-80 t/h).

Tab. 4: Technical parameter: Farm Bagger, type of fruit: grain corn (BELLUS et al., 2008)

Parameter	**Unit**	**Values**
Tractor: J.D.6520		
Motor	drivel/ min	2050
Power take-off	drive / min	505
Grain corn, moisture	%	23,1
Broken grain harvest	%	8,1
Broken grain in the bag	%	8,6
Broken grain caused by Farm Bagger	%	0,55
Technical performance	t/h	366
Technological performance	t/h	259
Performance, Front loader	t/h	122
Consumption of diesel (technical)	l/t	0,03
Consumption of diesel (technological)	l/t	0,04
Operational reliability	%	100

3.4 Roller mills (Grinder Bagger) with adapter for bags

Fig. 5: Roller mill with bag adapter

Roller mills (Grinder Bagger) equipped with a bag adapter are also used for storing grain in silage bags (fig. 5). Wet grain (as feed or energy feedstock) is milled in a single process, afterwards mixed with preservatives and finally pressed into the bag. Besides, the preservation of wet grain saves drying (energy), labour and storing costs.

In addition to grain, maize corn, grain legumes, rape and other threshing fruits can be processed as well. The fineness is determined by the rollers corrugation and distance.

After demounting the rollers also whole corn can be pressed into a silage bag by means of the Grinder Bagger (bag diameter 1.50 m or 1.95 m).

The machine is filled by dint of a front loader or auger. The performance (milling and storing) depending on the fineness (rollers surface) is between 20 t/h (1 double roller) respectively 60 t/h (2 double roller). Of course, the performance after demounting the rollers for storing whole grain is accordingly higher and again dependent on the filling power.

3.5 Removal from silage bags

For removing whole grain from the silage bag front loaders, blowers or special removal technologies can be applied. This tractor-driven device winds up the film during the removal (fig. 6). By means of a transversal screw conveyor the grain will be removed and afterwards transported by an unloading auger into the transportation unit. Hence, a performance of up to 280 t/h can be achieved.

Fig. 6: Special removal technology for grain

Milled grain can be removed with common technologies currently available on farms. Basically, an efficient removal is possible by using devices known from the removal out of bunker silos considering some basic rules. In this connection slicing the bag correctly is very crucial. According to analyses taken by the University of Göttingen (KIRCHHOFF, WEGENER, 2009) the slicing took no longer than two minutes.

The plastic tube should be sliced about 20 cm above the ground laterally commencing and semi-circularly over the entire cross section (U-shape). In addition, the film should lie on the floor lengthwise so that at least one axis of the removal vehicle stands on the film (fig. 7). Thus one can dig with slight pressure on the fixed film.

Fig. 7: Removal out of the silage bag

The performance depends both from the substrate and from the removal technology. The bag diameter influences only significantly the performance using the milling method.

By storing the silage bags on paved surfaces and following the recommendations for slicing the bag it could be observed in practice that this will minimize manual labour and that there are less residues of film remaining in the fodder and less residues of fodder spread around the silage stock. In addition, the driver’s skills have a big impact on the success of the removal of harvested feed (KIRCHHOFF, WEGENER, 2009).

3.6 Film quality of silage bags

While bunker silo films mostly contain several amounts of recycled material silage bags were made of exclusively primary raw materials due to the high quality requirements (tear strength, ultimate elongation). The film thickness depending on the bag diameter is usually about > 200 µm. However, considering only the quality criterion can lead to false estimations. (STEINHÖFEL, WEBER, MEISE, 2006).

The film surface of silage bags compared to the silo content is quite large. In additional, due to the silo press's compaction process high mechanical strains caused by compressive and tractive forces occur, which on the other hand appear only barely using bunker silo films. As a result, parameters like ultimate elongation, tear strength, shearing and particularly the puncture resistance (dart drop) are highly important in this context. Table 5 is supposed to give an overview of the DLG-standards for awarding the seal of approval for bunker silo film with a thickness of 200 µm. In contrast internal minimum quality standards for a silage bag with a diameter of 2.70 m are presented as well. It is clear that there are significant differences in minimum requirements.

Tab. 5: DLG standards for silo films up to 200 µm and internal minimum standards for silage bags with a diameter of 2.70m (STEINHÖFEL, WEBER, MEISE, 2006)

Parameter	**Unit**	**DLG Standard film for bunker silos**	**Minimum standard 2,70 m bag**
Recycled material		possible	without
Film thickness	µm	200	215
Deviation - nominal thickness	%	± 5	none
Deviation - single values	%	± 15	± 12
Tear strength	N/mm²	≥ 17	> 23
Ultimate elongation	%	≥ 400	> 750
Shearing	g	-	> 1.800
Dart drop	g	-	> 800
Gas-permeability	cm^3O_2/m^2	< 250	< 200
UV resistance	months	Manufacturer-specific	24

Whilst silo films with the mentioned technical properties usually can protect a silage reliably for one year, when properly used, silage bags must have considerably higher technical values owing to the specific requirement profile.

The silo bag's colour (measured by exposure value and whiteness) plays probably an increasingly important role than it does when using bunker silo films. Thus, in summer it could be possible that the seasonal warming cause an elongation of the bags. In worst case a reduced whiteness can lead to an increased warming and so to a tearing of the bag due to the high compressive and tractive forces. Besides, the friction coefficient is of great importance when using the silage bag technology. So, if it is too high, several folds could be slip down from the tunnel. The operator would be involved in considerable additional expense to put the film back on the tunnel.

The UV resistance of the film against the corrosive effect of solar radiation is usually undervalued. Even assuming that silos on average do not longer last than 12 months, this assumption can not be risked for film tubes. The highest standards in Central Europe recommend a stabilisation period of 24 months (the intensity of solar radiation is position-dependent), but minimum 18 months, what advances the price for foil. Given that silage bags in contrast to silo bunkers are subjected to higher compressive and tractive forces, an earlier degenerating of the film can have a dramatic impact and finally lead to a bag bursting. The gas-permeability of the foil is strongly dependent on its thickness. Since the quality film tubes made of better raw material are generally thicker than 200 µm and thus the gas permeability considerably exceeds the DLG norm, this question does not even arise.

4. storage of grain in silage bags – quality aspects

4.1 Practical experiment for storing consumer wheat in silage bags

How quality parameters can be influenced during a six-month storage of consumer wheat in silage bags, which was harvested with a storable dry-mater content? The answer to this question was target of a practical experiment. In this context 2008/09 first scientific investigations were accomplished in Germany relating to the storage of grain in silage bags (Leibnitz-Institut für Agrartechnik Potsdam Bornim in cooperation with BAG Budissa Agroservice GmbH) (WAGNER, IDLER, 2009).

Tarso wheat with a moisture content of 10,9 % and with a yield of 87 dt / ha was harvested by Budissa Agrarprodukte Preititz / Kleinbautzen GmbH. The content of crude protein was 14,8 % DM, the starch content 67,2 % DM, the falling number 407, the HL weight 79,6 and the sedimentation value 43.

By dint of a Farm Bagger 75 t of grain were stored in two silage bags (diameter of 2.70 m) (fig. 8). In bag 1 four valves were installed on each long side for later regular sampling; bag 2 was equipped with only 4 valves on one side. Bag 2 should only be sampled after six months to eliminate possible changes in quality due to the sampling itself.

In additional 8 data logger were inserted through the valves in bag 1, only 4 in bag 2 to determine the temperature profile. The bags were covered with a protective net against birds and with sandbags. A control batch remained in the warehouse (fig. 8) where the grain already had been stored after harvesting. Four data logger were inserted in this pile of wheat.


Fig. 8: Silage bags filled with wheat and warehouse alternative for comparison

In the following, after 14 days, after 4 weeks, after 3 and 6 months samples from bag 1 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.

Sample taken from bag 2 were considered just after six months of storing. For all types of storing the temperature profile was determined during the storage period.

The following parameters of each sample were investigated after the methods of VDLAFA: dry-matter content, pH-value, starch and crude protein and also the content of bacteria, yeasts and moulds. In additional, after six months an evaluation of the germination behaviour by determining the germination potency and germination ability took place.

Bag 1and bag 2 showed approximately the same temperature profile: a gradual decent of temperature and an approximation towards the ambient temperature (AT). Moreover, the profiles imply very low microbiological activities (fig. 9).

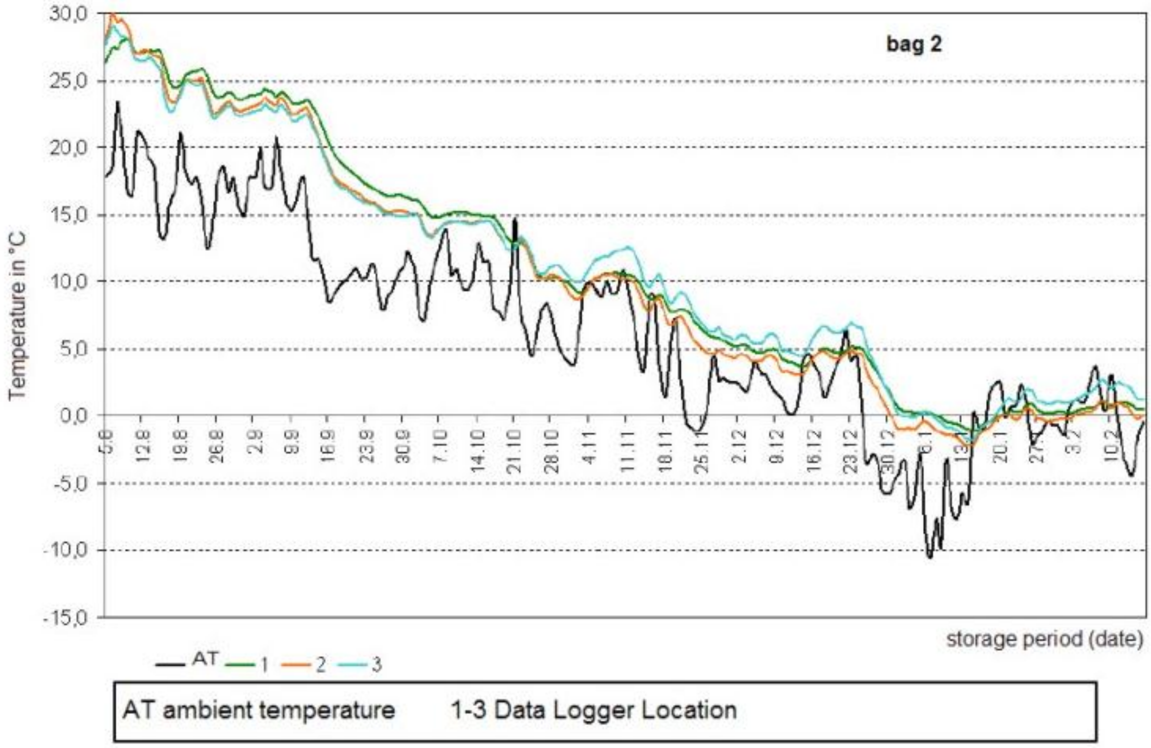

Fig. 9: temperature profile of bag 2 and ambient temperature during the whole storage period (WAGNER, IDLER, 2009)

A comparison of chemical and microbiological parameters of both storage varieties (bag and warehouse) show a nearly similar run of curves (fig. 10). The ingredients crude protein and starch, which were already detected before storing, still exist in nearly unchanged contents after a six-month storage period in silage bags. Also the pH-value remains the same and there no increase of micro organisms was registered. The contents of all investigated microbial groups are in range of the reference value for cereal products of DGHM (2007).

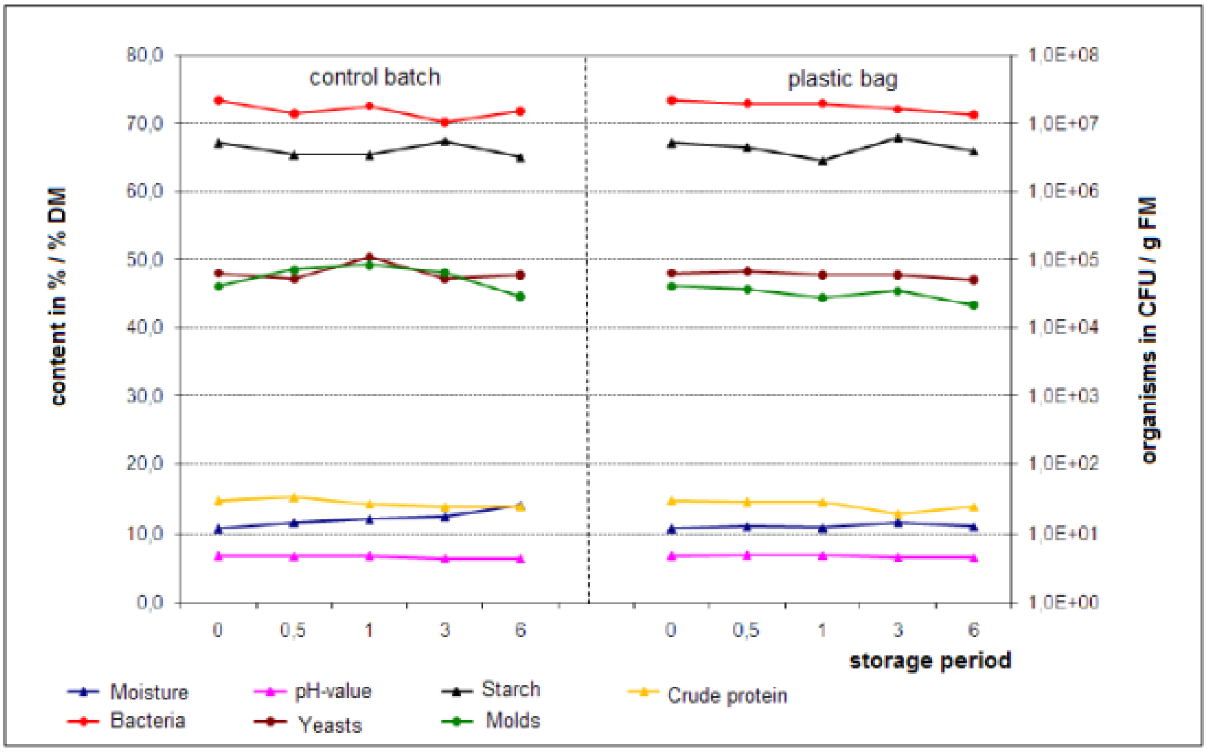

Fig. 10: Chemical and microbiological parameter of wheat during a six months storage, depending on storage type (WAGNER, IDLER, 2009)

With this practical experiment it could be proved that wheat, harvested with a storable DM value, could be stored up to 6 months without any quality losses.

The germination ability was determined after a 6 month storage period. From each variety (control batch, bag 1, bag 2) 4x100 wheat grains have been placed to rule in Petri dishes (Ø 15 cm) and stored at 20°C**.** 2 dishes of every variety have been kept cool at 4°C for 3 days to break a possibly existing dormancy. The germinated wheat grains (visible radix) have been removed daily. Finally after 5 days the germination ability was specified in %. In tab. 6 the germination ability after 6 months of storage, depending on the storage type is shown. A pre-cooling was not necessary i.e. the grains were not in dormancy. The germination ability of the samples taken from the control batch was on average with 98% slightly higher than the germination ability of samples taken from the bags with 94%.

After the last sampling the germinating potency of every variety (control batch, bag 1, bag 2) was stated at 2x50 wheat grains by means of the TTC-test (TTC: 2-, 3-, 5-Triphenylterazoliumchloride, MERCK 8380). Therefore the grains have been soaked in 40 °C warm water for approximately 30 minutes and afterwards cut in half length-wise with a scalpel. The grains have been bisected so that the seedlings are clearly visible. Only one half of each grain was to be tested. The halved grains were covered completely with a 5 % solution of TTC and after an hour of incubation at 35 °C the red-coloured seedlings had been counted. At least a third of the coloured seedlings indicate the presence of active enzymes for germination. The germination potency (tab. 7) was on average with 97% very similar to all samples. The main part of the grains is half-coloured. After 6 months of storing in bags the wheat showed the same germination behaviour as wheat stored in a warehouse.

Tab. 6: Germination ability of wheat after 6 months of storing, depending on the storage type (IDLER, 2009)

Sample		**Number of germinated grains after**					**Amount**	**Average**
		1d	**2d**	**3d**	**4d**	**5d**		
Control batch	K1	0	80			17	**97**	**98**
	K2	0	0			99	**99**	
	K3 [1)]			100	0	0	**100**	
	K4 [1)]			96	2	0	**98**	
Bag 1	K1	0	77			3	**80**	**93**
	K2	0	91			5	**96**	
	K3 [1)]			94	3	0	**97**	
	K4 [1)]			98	1	0	**99**	
Bag 2	K1	0	76			24	**100**	**95**
	K2	0	85			0	**85**	
	K3 [1)]			97	2	0	**99**	
	K4 [1)]			58	35	4	**97**	

[1)] pre-cooled

Tab. 7: Germinating potency of wheat after 6 months of storing, depending on the storage type (IDLER, 2009)

Sample	**Number of grains**					**Germinating potency in %**
	Not red-coloured	**Proportion of red-coloured grains**				
		¼	**½**	**¾**	**total**	
Control batch	1	16	27	6	0	98
	2	13	19	16	0	96
bag 1	0	19	21	10	0	100
	0	14	21	14	1	100
bag 2	5	23	15	7	0	90
	2	18	15	14	1	96

As well investigations in Texas revealed that within a short-term-storage of dry grain corn (< 14% moisture) over a period of at least 2 months no changes of the maize could be assessed. Even a decrease of the temperature in the bag during the storage was noticed. Also the content of aflatoxin did not increased and the amount of insects decreased due to the exclusion of air.

4.2 Investigations of milled wet grain in silage bags

The airtight storage of milled wet grain in silage bags was also investigated during experiments in 2006/2007 amongst others in Schleswig Holstein (MATTHIESEN, 2008). Among other things, the aim was to analyse the influence of moisture content on quality and stability. The storage of milled feed grain was done by the help of a Grinder Bagger (cp. Chapter 3.4).

Fig. 11: Experiments of wet grain conservation (Matthiesen, 2008)

These experiments (fig. 11) revealed that a low-loss storage in silage bags of all investigated types of wet grain under airtight conditions is possible independent from the moisture content. A stabilizing effect due to the formation of fermentation acids occurs in grain conditionally and only from moisture contents > 25% (tab. 8). Besides, characteristic differences between several types of grain could be shown. It could be demonstrated that wheat generally has a higher fermentation acid content as barley. Due to a moistening a doubled fermentation acid content in the silage can be achieved compared to freshly harvested grain with comparable moisture content.

Tab. 8: fermentation quality of wet grain in silage bags (without chemical preservatives) (MATTHIESEN, 2008)

	Unit	Barley		Wheat	
Moisture	%	31,4	17,4	26,6	21,1
pH	g/kg TM	5,2	6,1	4,6	6,1
Acetic acid	g/kg TM	0,8	0,3	1,6	0,1
Propionic acid	g/kg TM	0,2	0,1	0,1	0,1
Lactic acid	g/kg TM	2,1	0,1	6,9	0,2
Ethanol	g/kg TM	3,0	0,4	1,6	0,4
NH_4	mg/kg TM	378,7	88,4	249,8	59,1

By using the chemical preservative Kofa Grain pH 5 the fermentation indeed could be reduced explicitly, but the germination content could be reduced significantly. The result was that even with a minimal feed of one meter per week and with a dose rate of 4 l/t FM a sufficient stability of all types of grain could be achieved.

Thus, it is always recommended to use a chemical preservative. For a stable storage in silage bags damages caused by birds and rodents have to be avoided permanently by several protective measures (protective nets for silos, control round).

4.3 Storing grain silage bags – What needs to be considered?

The storage and durability of grain in plastic bags is based upon the starting material, the purpose and the storage duration. Table 9 shows a checklist for ensiling grain in silage bags. This checklist demonstrates that there are many combination possibilities for storing grain that are based on both the properties of the starting material and the intended use.

A farm which for example has to store wet grain temporarily due to a lack of drying capacities, can remove grain already after a short time in great quantities. In contrast, a farm which uses grain only for in-house feedstuff and which does not use the whole content of a silage bag, is subject to adverse conditions.

Tab. 9: Checklist for storing in silage bags

1	**Type of grain**	◊ Wheat ◊ Barley ◊ Maize ◊ _____________
2	**Field of application**	◊ consumption / seed cereals (go to 5.) ◊ in-house feedstuff ◊ Energy feedstock: biogas ◊ Energy feedstock: bioethanol
3	**Grinding and squeezing**	◊ yes ◊ no
4	**Chemical preservative**	◊ yes ◊ no
5	**Storage period (temperature)**	◊ up to 3 months. (autumn/winter) ◊ 3 - 6 months (spring) ◊ 6 - 12 months (summer)
6	**Removal quantities (feed)**	◊ whole content ◊ > 1 m per day ◊ < 1 m per day
7	**Moisture content**	_____ %

Ensiling grain in silage bags without adding a preservatives with the goal of subsequent drying (temporary storage, up to 3 - 6 months, especially during cooler seasons, thus by February or march at the latest) is possible, but also risky. In this connection an absolute tightness of the silage bags and a good compression (stretching strips) is very crucial.

For feed grain with the aim of a long-term storage it is recommended to grind the grain while adding a chemical preservative, what needs to be mixed homogenously with the grain.

At a moisture content of 17% and more a slight acidification (lactic and acetic acid) can occur what causes no disadvantages except some least biological losses. Through a subsequent drying acids become volatile. Depending on the weather a highly increased content of bacteria is expected already occurring on freshly harvested grain (see season 2010), especially yeasts and moulds. Due to the airtight storage their growth normally can be inhibited. However, they won’t die and when opening (oxygen supply) the bag they suddenly can multiply. Therefore a quite rapid removal after opening is required.

Due to fungal infestations on the field or in the warehouse toxins can form; outdoor moulds form toxins already before harvesting. For these toxins there are several limits, whose exceedance causes a prohibition of trade by law. Ensiling in silage bags doesn’t mean coercively an increase of moulds and thus possible formations of mycotoxins. However, a degradation of already formed mycotoxins doesn’t take place in the bag. In such cases it is recommended to analyse the starting material with the help of minimum one microbiological investigation of each bag. The content has to be tested on moulds, yeasts and on mycotoxins, aflatoxins, zearalenone and ochratoxins.

Operating instructions for storing in silage bags, above all the protection against damages and absolute gas tightness, must be observed.

Based on the checklist shown in table 9 it can be easily derived what is to consider and which recommendations have to be given. Those have to be consistent with research results.

5. Costs for storing grain in silage bags

5.1 Whole corn (free-flowing bulk-material) in silage bags

Whether the in-house storage of threshed fruits is profitable or whether the rental of warehouses gives a good return or if selling parallel to the harvest is the cheapest alternative, has to be assessed and decided individually (GRUBE, 2009). The procedural costs for storing grain in silage bags are composed of machine costs, labour costs and film costs. In a calculation example costs for using a filling screw were reckoned as well (fig. 12; tab. 10).

Fig. 12: Storage of grain with the help of a Farm Bagger and filling

Tab. 10: Calculation of costs for storing grain corn in silage bags

Matter of expense	Unit	Utilization (t/year) 5.000	20.000
Invest. Farm Bagger	€	17.000	
Invest. Filling screw		7.000	
Invest. Special removal technology		25.000	
Amount to be invested		**49.000**	
Operating life	**Years**	**6**	
Performance, storage	t/h	100	
Performance, removal	t/h	100	
<u>Silage bags:</u>			
Bag's diameter and length	m	Ø 2,7 // length 90 m	
Bag content	t	315	
Number of bags	n	16	63
Costs for storing and removing	€/year		
Depreciation, 6 years		8.170	8.170
ROCE[1] (1/2 capital, 6% per year)		1.470	1.470
Repairs (0,10 €/t)		1.000	4.000
Tractor [2]		4.500	18.000
Wages [3), 4)]		1.620	6.475
Foil costs		9.510	38.000
Total costs per year		**26.270**	**76.115**
Total costs per ton	€/t	**5,30**	**3,80**
There from foil costs (here without discount)		**1,90**	**1,90**

[1] Return on capital employed [2] storage 4,5 operating hours per bag, 50 € per operating hour (incl. diesel); removal: haulier 40 €/h [3] wage for storing and removing 15 €/h [4] storage 5 h per bag

The amount to be invested for ensiling grain in silage bags with a separate filling screw, Farm Bagger and relating special technology for removing are 49.000 EURO. This method amortises already after a short time (6 years) (planning certainty). Besides, with increasing utilization the machine costs will decrease, here for comparison 5.000 t and 20.000 t per year. The total costs of self mechanisation amount 3,80 €/t (20.000 t/year) respectively 5,30 €/t (5.000 t/year), depending on the tonnage. An additional surfacing of the area for laying down the bags would cause additional costs of about 2,00 € per ton with a calculated required floor space of on average 1 m²/t.

A cost comparison of different storage types storing about 2.000 t of wheat (outdoor round silo, flat stores with steel cells and silage bag) results in cost savings of over 50% using the silage bag technology (concreted surface, with special removing technique) (GRUBE, 2009). For storing 2.000 t of wheat in flat stores a total amount to be invested of 244.360 EURO for an already built flat store or respectively 364.734 € in case of a new building was calculated. In contrast, a round silo (elevated tank) was calculated with 223.000 EURO (Tab. 11).

Tab. 11: Costs of storing wheat (GRUBE, 2009)

	Round silo (2.000 t)	**Flat store (2.160 t)**
Total amount to be invested	**222.901 €**	**364.734**
Depreciation (18 years)	12.844 €/a	22.638 €/a
Interest	6.486 €/a	9.738 €/a
Maintenance	1.056 €/a	1.283 €/a
Fixed costs	**20.386 €/a**	**33.660**
Working materials, repairs	4.631 €/a	4.939 €/a
Wage rate	3.104 €/a	1874 €/a
Variable Costs	**7.735 €/a**	**6.813**
Total costs	**28.121 €/a** **14,06 €/t**	**40.473 €/a** **18.74 €/t**

With costs of 100 €/t the investment volume for storing conventionally 10.000 t of grain in elevated tanks or in flat stores is therefore in range of one million.

Costs resulting from the in-house storage are determined substantially by the size of investment costs, since the depreciation accounts for about 60-75% of costs (RUCH, 2009). To avoid the relatively high investment risk and to ensure the liquidity there is also the possibility to store the grain externally for a short time. Storing grain by the agricultural e.g. of Hessen costs on average about 20 €/t depending on the storage life.

5.2 High-moisture grain and corn: milling and storage in silage bags

Especially the drying of grain corn has to be questioned since there are increasing drying costs and on opposite low prices for grain and maize. Hence, it is advisable to conserve high-energy forage by oneself. Costs of wage labour for the production of maize immediately ready for feeding and for the storage in silage bags are about 13 €/t. The use of silage additives can be minimized due to the complete exclusion of air (MATTHIESEN, 2008). Advantages of this method are also the high flexibility and the low amount to be invested (Tab.12).

Tab. 12: What to do with 1.000 t of wet maize (35% moisture) from the field? (STEINHÖFEL, WEBER 2008)

Criteria	Drying, wage	Harvestore, own	Acidic preservation, own	Roller mill, Wage work, Silage bag	Roller mill, own, silage bag
Costs	30 €/t	21 €/t	15 €/t	13 €/t	10 €/t
Investment	-	175.000	5.000	-	70.000
Capacity (t/a)	unlimited	1.000	unlimited	unlimited	15.000
Operating life (risk)	-	15	5	-	3
€/year	29.700	21.000	15.000	13.000	10.000
relatively	297	210	150	130	100
Additional expenditure	19.700	11.000	5.000	3.000	0
Not taken into account	preparation, transports, storage	Protracted storage, underusage	Additional milling, Property costs	Costs per m², silage additive,	Costs per m², silage additive, additional utilization

Even with respect to common methods of conserving wet corn legumes with expensive additives ensiling in bags becomes more important referring to silages with higher physiological moistures, since cheaper additives can be used (THAYSEN, 2009).

Thus, such investments are not only profitable for contractors but also for large farms. The valuable forage is usually ensiled directly and ready for feeding near the stable. In the UV-stabilized silage bag it can be stored up to 2 years if it is protected against any damages (caused by e.g. birds, rodents).

6. Practical examples: grain in silage bags

The technology of grain storage (food and feed grain, both dry and wet) in silage bags is practiced for several years intensively all around the world e.g. in Australia, Argentina, US and in Russia. In Germany this method played only a minor role so far. Prices for grain were mostly stable for decades. Through this planning certainty silo buildings were clearly calculable. Intervention was a keyword that almost excluded any risk that grain couldn't be sold or only with great losses. For a few years, things have changed. Worldwide price fluctuations and speculations, which did not exist before, can occur within a few days. As experiences showed prices can rise or fall by 20%.

The sinus curve also known form the pig market could become normal for grain as well. According to this basis, investment decisions with regards to grain storage should be assessed again. Perhaps new is that farmers who previously could not store anything now want to participate more on post-harvest jumps in prices without making major investments at the same time.

6.1 Wet grain as whole corn in silage bags

Under the name ‚Vodka Sobieski' a lot of different products of vodka are produced in a little village between Gniezno and Poznan and sold in whole Europe. Its production is subject to the highest quality standards.
For 5 to 6 years moist corn is ensiled with a rotor machine, after initial tests, as whole grain in silage bags without any additives, up to now with an annual rate of 5,000 to 6,000 t. The main reason for this was an extreme reduction in costs, because a construction of a silo was not necessary. But most of all the expensive drying of home-grown grain corn could be eliminated. That results in cost savings of at least 20 to 25 € per ton, since storing in bags costs only approximately 5 € per ton. All realized tests and the longstanding years of experience proved: with moist corn there are neither lower ethanol yields nor a modified quality of alcohol compared to dried corn. Since 2009 wet corn is stored as whole grain in silage bags and is subsequently processed by distillery owners in Bavaria.
2007 1,000 t of dry rye have been stored in Poland for the first time with the same machine in silage bags. Rye is the main raw material for the alcohol production. The expanding production of vodka would have required constructions of new silos. This could be avoided with storing the rye without any problems, even for longer periods, under absolute airtight conditions in silage bags.

6.2 Wheat and barley as whole corn in silage bags

In 2010 even on several farms in Saxony grain was stored by means of the Farm Bagger technology in silage bags:

- During the harvest season 2010 problems with the outgrowth increased significantly due to unfavourable moist conditions. Hardly any food qualities were harvested at the end. On an agricultural co-operative wheat with a moisture content of 16-22 % which was germinated was mixed with 4 l/t Kofa grain ph 5 and stored in silage bags. The good was marketed in winter as feed grain; a removal from the bag was done by special techniques for removing grain (s. chapter 3.5).

- On another farm in Saxony wheat with a moisture-content of 15 % which regularly should have been sold, was stored six weeks in silage bags to get more profitable prices. The removal was done by a blower. Due to the higher price the silage bag technology has proven profitable.

- Barley (14 % moisture) and wheat (13 % moisture) were stored at a pig farm in Saxony each as feed grain in silage bags. At this time the farm had some problems with pest infestations in the warehouse. The removal was done for two weeks in advance. The grinding was done by means of a mobile pulverizing mill and mixing plant

6.3 Wet grain and high-moisture corn milled in silage

Compared to the storage of whole grain the storage of milled wet grain in silage bags is more common. Machinery rings and contractors are offering this technology in different states. Background is each the improvement of labour economics and the economic situation. Ensiling in bags does not take longer than storing goods in already existing warehouses. On the contrary, the storage in self-constructed warehouses in old buildings needs even more time. Moreover, apart from the surfaced storage area there is no need to build more warehouses. Since the crushing is done during the ensiling process, the fodder can be removed and mixed directly without additional milling. With adequate controls the health maintenance of the grain is given, additional cleaning and drying can be omitted.

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