Impact of different drying techniques on hay quality

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Summary
In the years 2010 to 2012 a comparison of three different hay-drying-techniques was carried out at AREC Raumberg-Gumpenstein. The treatments „traditional field drying", „cold air ventilation" and „dehumidification drying" were tested with forage of permanent grassland, cut four times per year.

The results of chemical and organoleptic analysis showed advantages of the two ventilation drying treatments in terms of hay quality compared with field drying. Differences occurred for crude protein, β-carotene, digestibility of organic matter, energy concentration and some microbial germ groups but also for sensory parameters like smell, colour and dust. In 5 of 11 trials the dehumidification technique significantly resulted in better hay quality than ventilation drying with cold air and in 9 cases better results could be achieved compared to field drying. Technical disfunctions of the dehumidification technique caused negative effects on hay quality in 4 cases. During storage of hay quality losses concerning β-carotene, digestibility of organic matter, energy concentration and development of spoilage indicative micro-organisms occurred in all treatments, but were highest in the case of traditional field drying.

Introduction
Hay and aftermath hay are still important forage conserves for ruminants even though the proportion of hay has decreased in Austria from 54 % in the year 1994 (Wilkinson et al., 1996) to 23 % in 2010 (Resch, 2013a). In some disadvantaged mountainous regions of Austria the production of „hay-milk" is preferred by more than 8,000 farmers (fig. 1), because some sorts of special hard cheese are made of clostridia-free unpasteurised milk. 15 % of milk production in Austria is hay-milk, which in the meantime has become a very successful brand. Austrian hay farmers are located at an average altitude of 850 m (Resch, 2013b). The working committee of Austrian hay-milk farmers improved hay farming by a quality orientated marketing concept which resulted in increasing sales quantity of hay-milk products in Austria and foreign countries during the last years. On the other hand costs of concentrates are rising, so hay-milk farmers think more about strategies to improve forage quality. Approximately 24 % of profits in milk production depend on forage and its quality (Stockinger, 2009), therefore own conserved forage will be more important for successful farmers. Most of the forage in Austria originates from permanent grassland which is cut 1 to 4 times per year (max. of 6 times in Rheintal/Vorarlberg).

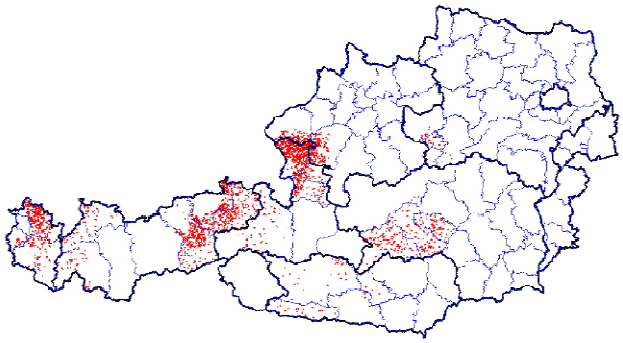

Figure 1: Designated areas with renunciation of silage production(BMLFUW, Invekos 2012)

Traditional field drying of forage is only using solar energy but this treatment takes a long field drying period with a high risk of unstable weather conditions. Dry matter contents of approx. 800 g kg^{-1} lead to increasing quality losses by spalling of leaves (Resch, 2009) and to the risk of massive propagation of epiphytic micro-organisms (Adler, 2002) in clammy grass.

Indoor drying technique basically allows to harvest forage with higher moisture contents. This reduces the field time, the risk of unstable weather conditions and the leaves spalling. But on the other hand it is a challenge for indoor drying techniques, to reduce the water content of forage within a short period as possible to avoid microbial spoilage of hay. Farmers should be familiar with the physical characteristics of forage and with the technique of the drying system, otherwise costs grow up and hay quality decreases.

The effect of a cold air drying system is limited by forage water content, air temperature and relative humidity, especially if it is cold outside in the night or air humidity is high (Nydegger et al., 2009). Ventilation with cold air reduces the efficiency of hay drying in comparison with warm air ventilation.

Treatments with air warming or dehumidification are performing better under worse environmental conditions, because they are able to remove suitable volumes of water from forage (Gindl, 2002). It is even possible to dry fresh grass by warm air, but drying costs are unecomically high in this case.

During the last decades forage science was focussed on silage conservation, whereas hay was disregarded. There is only little knowledge existing about the influence of modern drying technologies on hay quality in Austria. Experimental tests of different hay drying systems under comparable conditions were therefore necessary to provide results about mass- and quality losses during the conservation process from field to storage until feeding.

Objectives

The Agricultural Research and Education Centre (AREC) Raumberg-Gumpenstein has given a special focus on hay-quality with several projects carried out since 2007. Within the current project „Hay drying" different hay drying treatments were tested under defined conditions to provide conclusions and recommendations for farmers. The following areas were worked on:

- Technical aspects of hay drying treatments including energy consumption
- Measurement of leave spalling
- changes of hay quality during the conservation process
- changes in microbial status of hay
- feed intake, performance of dairy cows and milk quality
- analysis of costs and benefits of conservation treatments

Material and methods

A comparison of three different drying techniques for hay („traditional hay drying", „cold air ventilation", „dehumidification drying") was examined over three years (2010 to 2012) and different grassland cuts (1. to 4.) at AREC Raumberg-Gumpenstein. The experiment also included the factor storage period to determine quality changes of hay. The forage material was harvested on a permanent grassland area of in total 12 ha. The average floristic composition of the first growth was 57 % grass, 21 % legumes and 22 % herbs. In the year 2012 only three cuts were harvested because the third cut was destroyed by a flood. The harvest was managed by practice comparable machinery (Pöllinger, 2014, Resch, 2014).

Chemical and organoleptic analysis

Sampling was done by a sharpened steel drill tube (5 cm internal diameter), taking more than 20 randomised points of a forage wagon load. During the storage period hay samples were also taken from a minimum of 20 different spots to a depth of approx. 150 cm. Dynamic sampling was done at the harvest time, 7, 14, 30 and 60 days after harvest and at the beginning of feeding. The primary sample was split into subsamples for the following laboratories: AREC Raumberg-Gumpenstein, forage laboratory Rosenau (LK Niederösterreich) and AGES Linz.

Gravimetric analysis of absolute dry matter was carried out by drying at 105 °C during 24 hours (VDLUFA 3.1). For analysis of quality parameters a minimum of 300 g sample was dried during approx. 48 hours at 50 °C. Average grade of grinding was 1.0 mm. Chemical analysis of substances (Weender, structural substances, HCl-insoluble ash) and mineral macro and micro elements were carried out at AREC according to the VDLUFA book of methods. Digestibilty of organic matter was measured by the in vitro two-stage method (Tilley and Terry, 1963). Forage energy (ME and NEL) was calculated by regression coefficients on the basis of relationships between dOM and ME or NEL (DLG tables of forage for ruminants, 1997). For analysis of water soluble carbohydrates (sugar) and carotene, samples were freeze-dried and then ground to 1 mm particle size. Sugar and carotene analysis were carried out at forage laboratory Rosenau. Organoleptic evaluation of samples (smell, colour, structure and earthy contamination resp. dust) was done with the fresh material according to the ÖAG-sensoric test (Buchgraber, 1999).

Microbiological analysis

Enumeration of aerobic mesophile bacteria, yeasts, moulds and *Dematiaceae* was determined by VDLUFA-method 28.1.2 to validate microbial quality of hay samples. After a fresh sample was shred by scissors a suspension with bufferd pepton-solution (20 g of sample and 380 ml suspension) was produced in decimal dilution series. Count plates were made of suitable dilution steps with one culture medium for bacteria (Tryptose Agar with TTC) resp. with two culture media for yeasts, molds and *Dematiaceae* (Bengal Red Chloramphenicol Agar with Tergitol and Dichlorane Glycerol (DG 18) Agar). Inoculated count plates were count after appropriate time of incubation. Microbiological quality assessment was carried out on base of orientation values for microbial groups by VDLUFA-method 28.1.4 (tab. 1). Fresh harvested hay often has higher germ contents of product-typical micro-organisms as it is specified in the scheme of orientation values. If storage conditions are good, germ contents decrease during a few weeks (Bucher and Thalmann, 2006).

Table 1: Orientation values (in 10^6 cfu g^{-1} resp. 10^3 cfu g^{-1}) of VDLUFA for product-typical and spoilage-indicating micro-organism in hay, pooled in microbial groups (MG) 1 to 7 (VDLUFA 28.1.4)

Microbial Group (MG)			**orientation value**
	Mesophile aerobic bacteria	**important indicator micro-organisms**	**x 10^6 cfu g^{-1}**
MG 1	product-typical	Yellow pigmented bacteria, Pseudomonas, Enterobacteriaceae	30
MG 2	spoilage-indicating	Bacillus, Micrococcus	2
MG 3	spoilage-indicating	Streptomycetes	0,15
	Moulds and Dematiaceae		**x 10^3 cfu g^{-1}**
MG 4	product-typical	Dematiaceae, Acremonium, Fusarium, Aureobasidium, Verticillium	200
MG 5	spoilage-indicating	Aspergillus, Penicillium, Scopulariopsis, Wallemia	100
MG 6	spoilage-indicating	Mucorales	5
	Yeasts		**x 10^3 cfu g^{-1}**
MG 7	spoilage-indicating	all species	150

Orientation values of VDLUFA 28.1.4 are upper limits of microbial numbers for hay of normal condition (see tab. 1). For description of quality four quality levels (QL I to QL IV) were defined. QL I: normal status – corresponds to microbial numbers up to orientation value as a maximum. QL II: the microbial number for at least one group exceeds the orientation value up to fivefold. QL III: the microbial number for at least one group exceeds the orientation value up to tenfold. QL IV: the microbial number for at least one microbial group exceeds the orientation value more than tenfold. In this case spoilage of forage is evaluated.

Statistical analysis

All data of this project were entered into a MS-Access database and then controlled for correctness and plausibility. Descriptive analysis was done by Software SPSS (version 21), multifactorial GLM-analysis by STATGRAPHICS Centurion XV (version 15.2.14). The experimental design considered correct statistical analysis of main effects and interactions between the investigated factors drying technique, growth, storage period and year. From each quality parameter analysis of variance components was carried outto quantify the proportion of variability for each factor. Because of the comprehensive amount of results only a few selected statistical effects are presented in this paper.

Results and discussion

Concentrations of nutrients, digestibility of organic matter, sugar, vitamins and microbial status are helpful and important parameters for the evaluation of hay quality. The following results are representing the comparison of three different hay drying treatments tested in 11 exact trials and carried out in the years 2010 to 2012.

Ingredients of hay

It is of great importance in the conservation of hay to raise the dry matter content quickly above 870 g kg^{-1} FM (Nydegger et al., 2009) to ensure microbial stability for the storage period. Meisser and Wyss (1999) recommended a minimum DM of 850 g kg^{-1} FM for hay. Precious plant leaves are sensitive against spalling losses and with an increasing DM content more leaves are destroyed by mechanical work.

Multifactorial analysis showed high significant effects of the factor growth on all ingredients (p-values in tab. 2 < 0.01). Estimation of variance components indicated highest effects of growth on crude protein, natrium and copper. An increase of crude protein (121.7 to 171.9 g kg^{-1} DM) could be noticed from the first to the fourth cut whereas crude fibre dropped from 251.4 to 195.5 g kg^{-1} DM. The development of structured carbohydrates (NDF, ADF, ADL) was not non-linear in comparison with crude fibre (tab. 3). The first growth provided the highest sugar contents (154.4 g kg^{-1} DM), the lowest were measured in the third growth with 120.7 g. Hay of the fourth growth had the highest average β-carotine content of 117.6 mg kg^{-1} DM. Crude ash was increasing during the course of vegetation period with 75.1 (first cut) to 109.3 g kg^{-1} DM (fourth cut) and there was also a clear trend for the sand-content (HCl-insoluble ash, tab. 3). Sand values from the third and fourth cut exceeded 20 g kg^{-1} DM which is according to Resch et al. (2013) an indicator for earthy contamination of forage.

Significant effects on forage ingredients were observed for the factor year (tab 2) which for approx. 70 % of parameters was identified being the most influencing factor on data variability. Under comparable conditions

the factor drying-treatment had a high significant effect on crude protein and β-carotine content. The average effect of air dehumidification drying was +4.9 g XP kg^{-1} DM compared with traditional field drying. Ventilation drying (cold or warm air) increased β-carotine content (+25 mg kg^{-1} DM) in opposite to field drying (tab. 3).

Table 2: Main effects and interactions of the factors year, growth, drying treatment and time of storage on different quality parameters of hay (p-values and r²)

factor	DM	XP	XF	NDF	ADF	ADL	NFC	XS	XL	XA	sand	carotene
year (y)	0,015	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
growth (g)	0,002	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
drying technique (d)	0,106	0,042	0,914	0,527	0,647	0,388	0,884	0,187	0,257	0,952	0,532	0,000
storage time (s)	0,000	0,015	0,554	0,143	0,690	0,850	0,094	0,625	0,000	0,817	0,987	0,000
d x y	0,354	0,552	0,621	0,949	0,632	0,728	0,948	0,044	0,994	0,778	0,586	0,000
d x g	0,142	0,820	0,797	0,710	0,857	0,004	0,849	0,022	0,165	0,950	0,944	0,051
d x s	0,000	0,547	0,858	0,740	0,977	0,281	0,978	0,853	0,725	0,994	0,999	0,389
s x y	0,004	0,498	0,834	0,273	0,951	0,308	0,352	0,997	0,000	0,921	0,958	0,002
s y g	0,982	0,057	0,967	0,592	0,877	0,438	0,665	0,991	0,064	0,992	0,985	0,002
R^2	0,865	0,832	0,572	0,627	0,537	0,716	0,469	0,767	0,769	0,624	0,598	0,891

p-values refered on confidenzlevel 95 % (method LSD)

Time of Storage had a statistical impact on DM-content, especially in first week after harvesting. The utilisation of ventilation techniques enabled DM-contents above 870 g kg^{-1} FM within 7 days, whereas traditionally dried hay didn´t achieve 860 g DM kg^{-1} FM during the total period of storage (fig 2). β-carotine content decreased by 40 mg kg^{-1} DM resp. 38 % from the time of harvest to the date of feeding. Crude fat (XL) remained relatively steady in the hay samples at a level of approx. 21 g kg^{-1} DM. Arrigo (2010) observed an increase of +5 to +10 g XL kg^{-1} DM from the first to the third cut of hay in Switzerland . The same trend was described in the forage value tables for alpine regions (Resch et al., 2006).

Table 3: Impact of year, growth, drying technique and storage time on different quality parameters of hay

average	count	DM	XP	XF	NDF	ADF	ADL	NFC	XS	XL	XA	sand	carotene
total	198	845,5	142,9	233,3	474,3	275,8	35,9	272,1	137,0	20,8	89,9	24,6	88,3
year													
2010	72	853,2^{b}	149,9^{c}	238,0^{b}	469,6^{b}	277,3^{b}	37,6^{b}	272,7^{b}	119,9^{a}	18,3^{a}	89,4^{b}	22,3^{a}	51,2^{a}
2011	72	837,3^{a}	142,2^{b}	240,0^{b}	497,8^{c}	292,1^{c}	43,9^{c}	256,0^{a}	129,8^{b}	20,0^{b}	84,0^{a}	21,5^{a}	133,8^{c}
2012	54	846,1^{ab}	136,7^{a}	221,8^{a}	455,3^{a}	258,1^{a}	26,3^{a}	287,6^{c}	161,4^{c}	24,2^{c}	96,2^{c}	30,1^{b}	80,0^{b}
growth													
1	54	846,9^{a}	121,1^{a}	251,4^{c}	504,1^{c}	285,4^{b}	37,2^{b}	283,4^{b}	154,4^{d}	19,9^{a}	71,5^{a}	12,8^{a}	73,5^{a}
2	54	860,5^{b}	134,0^{b}	247,1^{bc}	483,5^{b}	290,4^{b}	35,6^{b}	278,9^{b}	127,6^{b}	21,3^{b}	82,3^{b}	16,4^{a}	84,4^{b}
3	54	840,0^{a}	144,7^{c}	239,1^{b}	491,2^{b}	293,9^{b}	39,7^{c}	247,1^{a}	120,7^{a}	20,6^{b}	96,4^{c}	31,2^{b}	77,9^{ab}
4	36	834,7^{a}	171,9^{d}	195,5^{a}	418,2^{a}	233,7^{a}	31,2^{a}	279,2^{b}	145,5^{c}	21,4^{b}	109,3^{d}	38,1^{c}	117,6^{c}
drying technique													
traditional field drying	66	839,4	140,5^{a}	233,1	477,9	278,5	35,6	270,8	134,6	20,5	90,3	25,7	71,5^{a}
cold air ventilation	66	852,0	142,8^{ab}	234,2	473,4	274,3	35,4	273,4	139,4	20,8	89,5	24,6	97,1^{b}
air dehumidification	66	845,2	145,4^{b}	232,5	471,5	274,7	36,7	272,1	137,1	21,1	89,9	23,6	96,4^{b}
storage time													
0 (harvest)	33	717,9^{a}	145,1^{c}	230,2	463,7	269,3	34,7	281,5	140,8	20,6^{a}	89,1	24,4	102,2^{d}
after 7 days	33	874,5^{b}	138,8^{a}	235,7	472,8	276,0	36,5	280,1	137,0	20,4^{a}	87,9	23,8	100,6^{cd}
after 14 days	33	866,6^{b}	139,5^{ab}	237,2	486,6	281,3	35,9	264,7	137,6	20,1^{a}	89,0	24,3	96,4^{cd}
after 30 days	33	874,3^{b}	142,5^{abc}	235,0	474,4	276,7	36,5	272,8	136,7	20,4^{a}	89,8	24,8	92,1^{c}
after 60 days	33	875,4^{b}	144,3^{bc}	233,5	476,7	275,4	36,0	267,5	134,2	20,2^{a}	91,3	25,7	75,2^{b}
begin of feeding	33	864,4^{b}	147,3^{c}	228,1	471,3	276,4	35,9	266,0	135,9	23,2^{b}	92,1	24,9	63,4^{a}

units: DM [g kg^{-1} FM], carotene [mg kg^{-1} DM], other parameters [g kg^{-1} dM]

In comparison with classic crude fibre analysis, structured carbohydrates are representing nearby reality (Gruber 2009). Total content of structured carbohydrates (NDF) was similar for the first to the third cut (483.5 to 504.1 g NDF kg^{-1} DM) whereas hay of the fourth cut had significant lower NDF-contents (average 418,2 g kg^{-1} DM) which is typical for the Austrian situation in practice (Resch 2013b, 2013c). Lignin-contents (ADL) were definitely lower (35.9 g kg^{-1} DM, standard deviation +/- 9.1 g kg^{-1} DM) than the average situation in Austria without any influence of the factors drying technique or storage period.

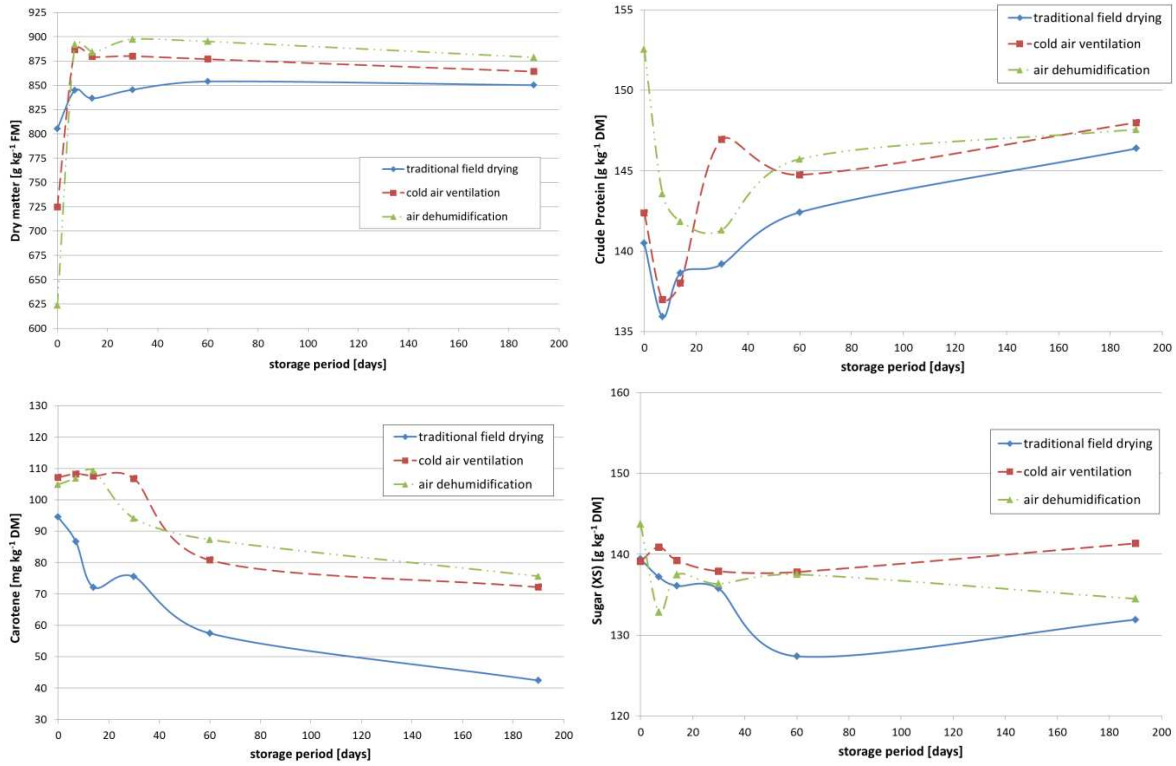

Figure 2: Influence of drying technique and storage period on DM-, XP-, carotene- and sugar-content of hay

In comparison to the average quality of hay in Austria (Resch, 2013c) much better values were found in our project for the first cut, whereas the aftermath quality was on the same level (Resch, 2014).

Digestibility of organic matter, energy content and sensory properties

Usability of forage can be classified by in vitro digestibility of organic matter (dOM). In opposite to the estimation of dOM on the basis of crude fibre (Gruber et al., 1997), the results of in vitro digestibility showed clear differences between the three drying techniques. A decreasing trend of digestibility during the storage period was observed. All tested factors significantly influenced the energy parameters ME and NEL (tab. 4).

Table 4: Main effects and interactions of the factors year, growth, drying treatment and time of storage on OM-digestibilty, energy concentration and sensory properties

factor	dOM	ME	NEL	smell	colour	structure	dust	points
year (y)	0,000	0,000	0,000	0,000	0,000	0,239	0,310	0,001
growth (g)	0,000	0,000	0,000	0,542	0,064	0,000	0,000	0,215
drying technique (d)	0,006	0,013	0,014	0,004	0,000	0,000	0,051	0,000
storage time (s)	0,149	0,020	0,041	0,008	0,380	0,055	0,011	0,003
d x y	0,143	0,169	0,178	0,075	0,004	0,021	0,617	0,009
d x g	0,184	0,265	0,271	0,011	0,053	0,017	0,264	0,021
d x s	0,985	0,996	0,996	0,583	0,935	0,759	0,942	0,842
s x y	0,924	0,966	0,965	0,806	0,596	0,160	0,104	0,710
s y g	0,130	0,202	0,160	0,702	0,706	0,234	0,035	0,399
R^2	0,666	0,668	0,669	0,454	0,509	0,595	0,490	0,502

p-values refered on confidenzlevel 95 % (method LSD)

Average hay quality in the year 2010 was significantly lower than in the following years 2011 and 2012 which might be caused by some technical problems with the air dehumidification in2010 (Fig. 4). Hay samples of the growths were significantly different in digestibility (tab. 5). Hay of the first cut had an average dOM-value of 72.6 % whereas aftermath hay of the third cut showed a low OM-digestibility of 64.2 % in all three years. Ingredients of hay like NDF, ADF, ADL or XS carried out no explanation for this dOM-depression.

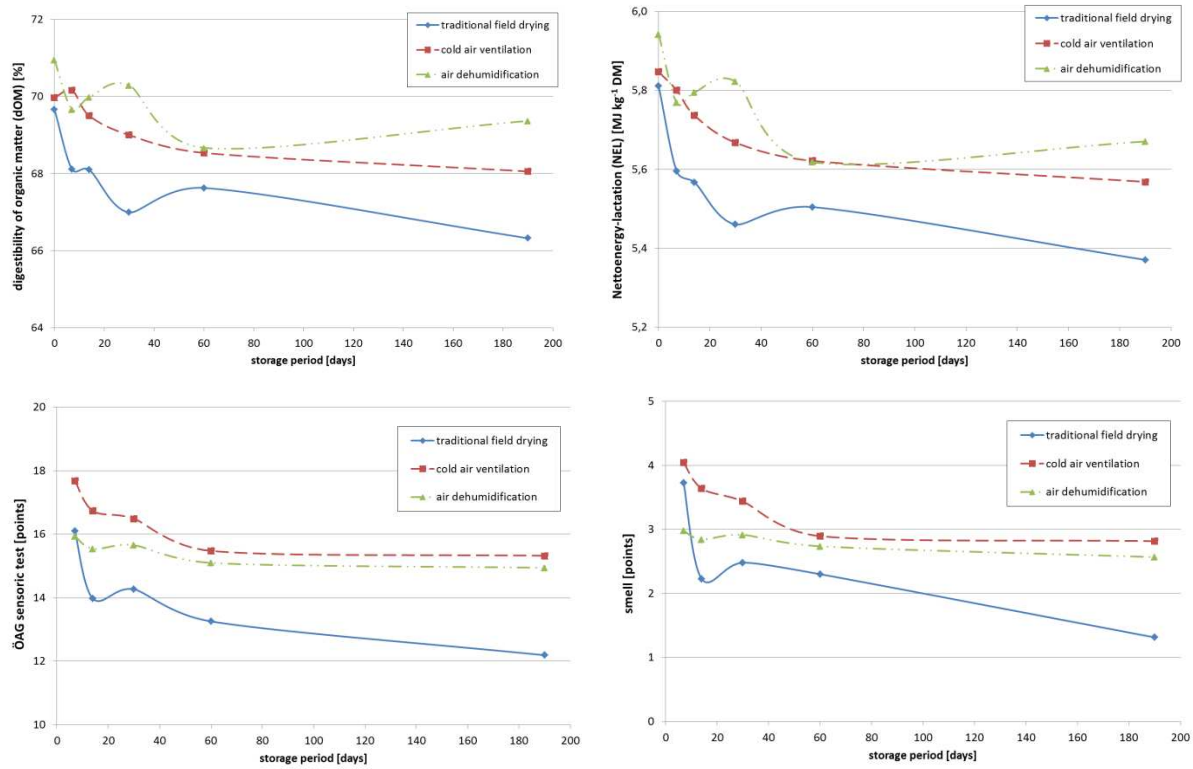

Figure 3: Influence of drying technique and storage period on OM-digestibility, net-energy lactation and parameters of the ÖAG-sensory test of hay

Hay conserved by traditional field drying had worse quality than hay processed with ventilation treatments. Quality differences between cold air ventilation and dehumidification drying were not significant (tab. 5). During the storage period a decrease of quality was observed in all treatments with an average reduction of OM-digestiblity from harvest to feeding of about 2.3 %. Quality losses of traditional field drying amounted to 3.4 %, that of cold air ventilation were 1.9 % and with dehumidification drying 1.6 % of OM-digestibiliy got lost during the storage period (Fig. 3). Loss of energy were determined with 0.4 MJ NEL kg^{-1} DM (traditional field drying) and ~0.25 MJ NEL kg^{-1} DM (ventilation treatments).

Table 5: Impact of year, growth, drying technique and storage period on OM-digestibility, energy concentration and ÖAG sensory properties of hay

factor	count	dOM	ME	NEL	smell	colour	structure	dust	points
total	198	68,9	9,62	5,68	2,9	4,0	6,7	1,7	15,2
year									
2010	72	66,6^{a}	9,25^{a}	5,42^{a}	2,2^{a}	3,7^{a}	6,6	1,7	14,2^{a}
2011	72	68,9^{b}	9,67^{b}	5,72^{b}	2,9^{b}	4,0^{a}	6,7	1,8	15,3^{b}
2012	54	71,4^{c}	9,93^{c}	5,89^{c}	3,5^{c}	4,5^{b}	6,8	1,5	16,2^{b}
growth									
1	54	72,6^{c}	10,33^{c}	6,17^{c}	3,1	4,0	6,4^{a}	2,1^{c}	15,6
2	54	69,2^{b}	9,76^{b}	5,78^{b}	2,9	4,2	6,8^{bc}	1,7^{b}	15,5
3	54	64,2^{a}	8,85^{a}	5,13^{a}	2,6	3,8	6,6^{b}	1,5^{ab}	14,6
4	36	69,8^{b}	9,54^{b}	5,62^{b}	2,8	4,3	6,9^{c}	1,3^{a}	15,4
drying technique									
traditional field drying	66	67,8^{a}	9,44^{a}	5,55^{a}	2,4^{a}	3,4^{a}	6,3^{a}	1,8	14,0^{a}
cold air ventilation	66	69,2^{b}	9,66^{b}	5,71^{b}	3,4^{b}	4,5^{b}	6,8^{b}	1,7	16,3^{b}
air dehumidification	66	69,8^{b}	9,75^{b}	5,77^{b}	2,8^{ab}	4,2^{b}	6,9^{b}	1,5	15,4^{b}
storage time									
0 (harvest)	33	70,2	9,92^{b}	5,87^{b}					
after 7 days	33	69,3	9,68^{ab}	5,72^{ab}	3,6^{b}	4,2	6,8	2,0^{b}	16,6^{c}
after 14 days	33	69,2	9,64^{ab}	5,70^{ab}	2,9^{ab}	4,1	6,8	1,6^{a}	15,4^{abc}
after 30 days	33	68,8	9,58^{a}	5,65^{a}	2,9^{ab}	4,1	6,7	1,7^{a}	15,5^{bc}
after 60 days	33	68,3	9,48^{a}	5,58^{a}	2,6^{a}	3,9	6,5	1,6^{a}	14,6^{ab}
begin of feeding	33	67,9	9,41^{a}	5,54^{a}	2,2^{a}	3,8	6,6	1,4^{a}	14,1^{a}

units: dOM [%], ME and NEL [MJ kg^{-1} DM], other parameters [points]

A comparison between the results of the hay drying-experiment and the field study „LK hay-project“ (Resch, 2010, 2011, 2013b, 2013c) showed interesting effects of drying techniques and cuts on the energy concentration (fig. 4). In the first growth the differences between drying treatments was higher than for aftermath hay. Technical problems with the dehumidification drying in the year 2010 caused a significant NEL-depression (fig. 4 left side). The average energy level of hay (2011/2012) in the experiment „hay drying“ was much higher than the energy level of hay from Austrian hay-milk farmers (fig. 4 right side). Disadvantages in practice caused from the later forage harvest.

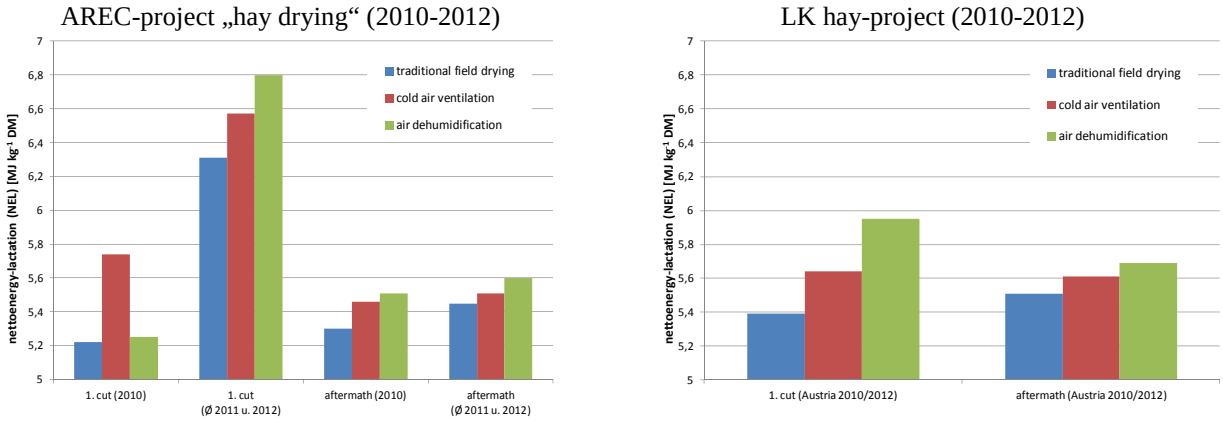

Figure 4: Influence of drying treatments on energy concentration of hay and aftermath hay (left side: AREC-project hay drying; right side: LK hay-project)

In the AREC-experiment „hay drying” also organoleptic observations concerning smell, colour, structure and contamination (dust, earth) were carried out. Sensory properties allow to draw advanced conclusions for hay and the effects of drying techniques. For sensory properties a significant effect of the factor year was found

(tab. 4), mainly caused by the bad conditions in 2010. The third cut showed significantly worse sensory quality. The drying technique had a strong influence on the conserved hay, especially on smell, colour and dust. The traditional field drying system resulted worst in terms of smell and colour but also in structure because of a lower leaf content (tab. 5).

Microbiological quality-status of hay

Product-typical microflora

In every year and for all drying techniques an almost similar field flora was determined. Bacteria flora was dominated by gram-negative germ groups like Pseudomonas and epiphytic Enterobacteriaceae. Beside yeasts there were different Hyphomycetes and Dematiaceae like Acremonium, Aureobasidium, Cladosporium, Colletotrichum or Verticillium and sometimes also toxigenic fungi like Fusarium and Alternaria occurred. Coelomycetes were detected at higher counts, especially the species Phoma and Ascochyta. The results are comparable with observations of previous AGES-experiments (Adler, 2002) and also with findings of other institutions (Brenton and Zwaenepoel, 1991; Wittenberg, 1997, Wiedner, 2008).

Table 6: Main effects and interactions of year, growth, drying treatment and time of storage on different microbial groups of hay (p-values and r²)

factor	product-typical			spoilage-indicating			
	MG 1	MG 4	MG 7	MG 2	MG 3	MG 5	MG 6
year (y)	0,098	0,784	0,018	0,000	0,000	0,075	0,001
growth (g)	0,000	0,000	0,000	0,001	0,032	0,000	0,000
drying technique (d)	0,701	0,020	0,000	0,007	0,053	0,003	0,000
storage time (s)	0,000	0,000	0,000	0,560	0,423	0,000	0,019
d x y	0,819	0,063	0,159	0,000	0,003	0,315	0,690
d x g	0,077	0,040	0,004	0,015	0,000	0,020	0,003
d x s	0,905	0,887	0,979	0,651	0,980	0,760	0,709
s x y	0,821	0,971	0,699	0,707	0,609	0,982	0,986
s y g	0,334	0,277	0,280	0,474	0,879	0,839	0,980
R^2	0,733	0,696	0,755	0,577	0,425	0,549	0,478

p-values refered on confidenzlevel 95 % (method LSD)

Numbers of product-typical bacteria (MG1) rised with every cut during the vegetation period (Adler et al., 2014). Fehrmann and Müller (1990) also found an increase of epiphytic flora on grass during the vegetation period. During the storage period composition of the microflora on hay changed because the primary flora of field-borne micro-organisms (relict flora) after harvest decreased relatively quickly. Reduction of the relict flora was higher in hay produced by traditional field drying than in hay treated with cold air ventilation resp. dehumidification drying (fig. 5). In hay samples with relevant storage flora a higher decrease of field flora was observed. Content of yeast showed an obvious reduction of germ count in every treatment. Yeast count of hay produced with the dehumidification drying system was > 0.3 log-steps higher during the total storage period than the other drying variants.

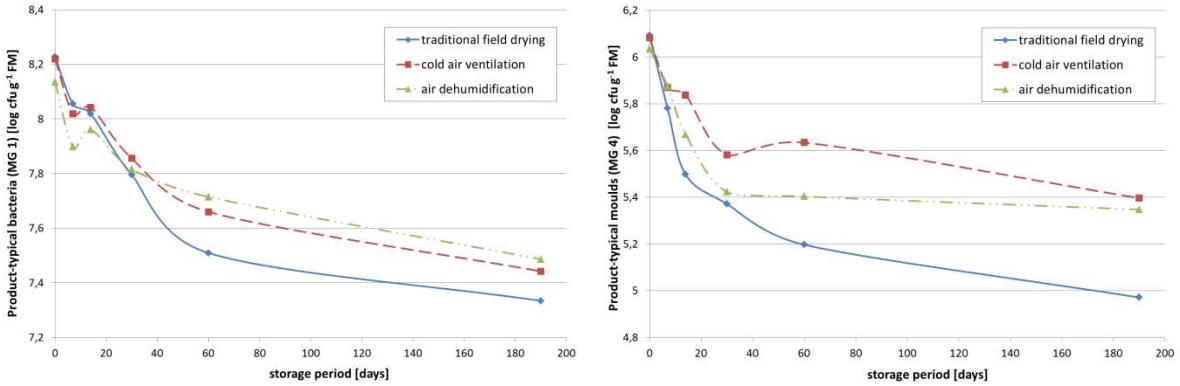

Figure 5: Influence of drying technique and storage period on product-typical bacteria (MG 1) resp. moulds (MG 4) in hay

Spoilage-indicating microflora

In the hay store the relict flora could be completed or replaced more or less quickly by a storage flora. It depends on water content and other factors (temperature, ventilation, etc.) what kind of storage flora is developing (Reiß, 1986). In hay of all treatments storage flora was characterised by little diversity of species. Spoilage indicating bacteria like Bacillus were predominant and sporadically Actinomycets occurred. Penicillium, Scopulariopsis and osmophile or xerotolerant fungi like Wallemia sebi, species of the Aspergillus glaucus-group or Mucorales dominated flora of storage-fungi. Especially in samples with high counts of fungi, Aspergillus niger and also Aspergillus fumigatus were detected. The observed flora of storage-fungi was according to other studies (Kaspersson et al., 1984; Undi et al., 1997; Reboux et al., 2006; Padamsee et al., 2012).

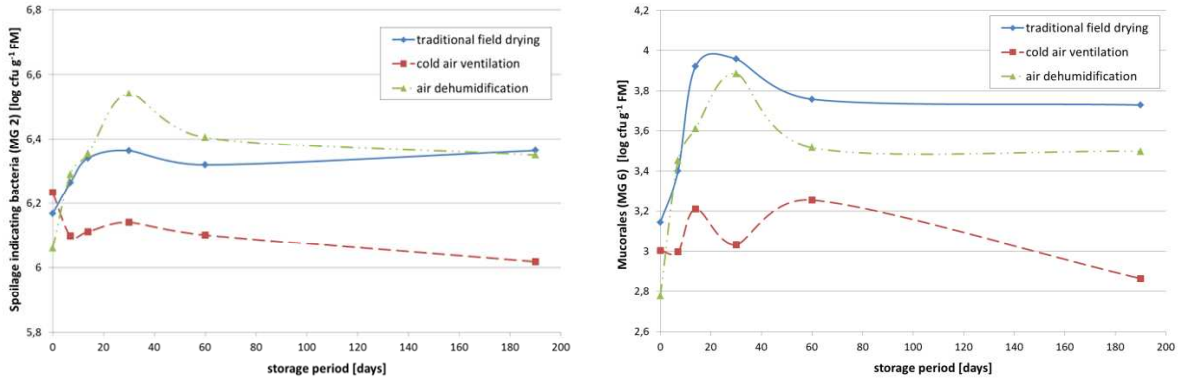

Figure 6: Influence of drying technique and storage period on spoilage-indicating bacteria (MG 2) resp. mucorales (MG 6) in hay

Hay of third or fourth cut showed consistently higher counts of storage fungi than hay of first or second cut. Reasons for more intensive development of fungi during storage could be changes in the structure of forage plants – fine or soft plant texture provide less resistance against storage fungi. High air humidity especially in late summer or autumn implies a bad drying-capability of air. Such conditions might result in an increase of fungi.

Traditional field dried hay had at least three times higher (> 0.5 log-steps) contents of important spoilage indicating fungi than hay produced by the other drying techniques.

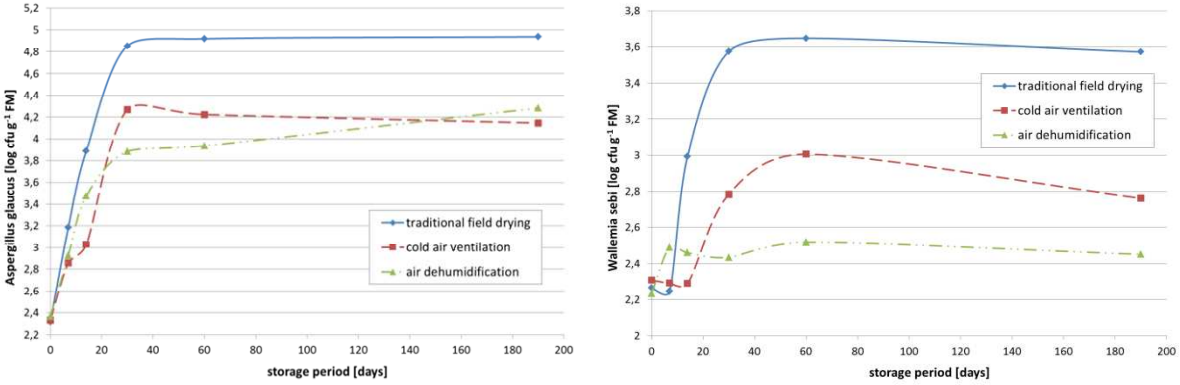

Figure 7: Influence of drying technique and storage period on Aspergillus glaucus resp. Wallemia sebi in hay

Hypothesis of microbial influence on in vitro-digestibility of OM

Results of project "hay drying" indicate a relationship between increase of numbers of spoilage indicating microbial groups and degradation of OM-digestibility during storage. GLM-model including the factors drying technique, growth, storage period, year and covariant germ group was chosen to test for the influencing effects (p-value) and to calculate regression coefficients for the correlation of different germ groups with dOM.

Table 7: Influence of different microbial groups on OM-digestibility of hay

microbial group MG	microbial species	p-value	microbial count [log cfu g^{-1} FM]	dOM [%]	regression coefficient [%]
MG 1	Yellow pigmented bacteria, Pseudomonas, Enterobacteriaceae	0,000	7,81	68,8	3,65
MG 4	Dematiaceae, Acremonium, Fusarium, Aureobasidium	0,000	5,57	68,8	2,64
MG 7	Yeast	0,466	4,68	68,9	0,37
MG 2	Bacillus, Micrococcus	0,035	6,27	68,9	-1,29
MG 3	Streptomycets	0,102	4,79	68,9	-1,64
MG 5	all species of MG 5	0,008	4,02	68,9	-0,74
MG 6	Mucorales	0,092	3,38	68,9	-0,57
MG 5-1	Penicillium	0,283	3,13	68,9	-0,32
MG 5-2	Aspergillus glaucus	0,001	3,68	68,9	-0,88
MG 5-3	Wallemia sebi	0,001	2,68	68,9	-1,07

p-values refered on confidenzlevel 95 % (method LSD)

In Tab. 7 some defined product-typical and spoilage-indicating microbial groups (VDLUFA 28.1.4) and their average effects on in vitro-digestibility of OM are displayed. For more detailed information group MG 5 was split in three sub-groups representing specific species (tab. 7). An increase of the counts of storage fungi by one log-unit caused a decrease of dOM (p-value < 0,01), in case of Aspergillus glaucus (-0,88 %) and Wallemia sebi (-1,07 %). The significant effects of product-typical groups MG 1 and MG 4 must not be overestimated, because only spoilage-indicating species could reduce easy utilisable nutrients like sugar and caused losses of digestibility of organic matter.

The results revealed that high counts of storage fungi in hay will adversely affect the digestibility of organic matter. Further experiments are necessary to confirm the causal correlation between increase of spoilage species and degradation of digestibility.

Conclusions

For more than 8.000 Austrian hay-milk farmers results of exact trials are of great importance to improve hay quality and to provide reliable decision arguments for selecting an optimal indoor drying technique. By means of the research project „hay drying“ carried out at AREC Raumberg-Gumpenstein three different hay drying techniques were tested in eleven exact trials under a four-cut-regime on permanent grassland. Under comparable conditions the ventilation techniques provided better hay quality than traditional field drying, especially concerning digestibility of organic matter, energy concentration and microbiological status. Dehumidification drying positively influenced the parameters crude protein, crude fat, and sand-content but the differences to cold air ventilation were not significant. Differences between dehumidification drying and cold air ventilation are not appearing if the year 2010 with some technical problems in the dehumidification drying treatment was eliminated from the statistical analysis. In five of eleven trials hay produced with the dehumidification drying showed better quality than that of cold air ventilation, in two cases hay quality was equal and in four cases quality was even worse, caused by technical problems. The primary problems of microbial spoilage are caused by to high water contents in the harvested forage in unfavourable combination with insufficient indoor drying. The risk of microbial spoilage is rather high for traditional field drying because of a strong development of storage microflora. The higher the water content in harvested forage the more important is a good performance and optimal management of the technical construction to produce best hay quality for dairy cows.

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