Long-term storability of different sugarbeet genotypes – Results of a joint IIRB study*

Einflussfaktoren auf die Lagerfähigkeit verschiedener Zuckerrübengenotypen – Ergebnisse eines IIRB-Forschungsprojekts

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In 2008/09 and 2009/10, storage trials with 12 sugarbeet genotypes were carried out under different conditions in six countries. The genotypes were grown in strips and harvested in September/November either by machine (using good agricultural practice) or by hand. Samples were then stored either in nets incorporated in clamps or in separate nets/bags or containers inside a barn or climate room. All samples were weighed and analyzed before and after storage for sugar (by polarimetry), potassium, sodium, amino nitrogen, total soluble nitrogen, sucrose, glucose, fructose, raffinose, betaine and glutamine content. After storage the samples were also examined visually.

Differences between the genotypes were observed for root tip breakage, sprouting, moulds and rot, although these differences were not unambiguous in all experiments and varied between the observations in the different countries. The sugar losses ranged from 0 to 66% of the initial amount and seemed to be related to various biotic and abiotic factors. Root damage by machine harvest and storage temperature were dominant factors in relation to the sugar losses. Genotypes also showed significant differences in sugar losses, but a strong interaction with year and site existed. Correlations could be found between sugar losses and initial sugar content (r = –0.66), initial betaine content (r = –0.62) and root tip breakage (r = +0.66) and after storage, moulds (r = +0.87), rot (r = +0.88) and invert sugars (r = +0.89).

Chemical analyses showed differences between the genotypes for the decrease in beet quality after storage, not only by a reduction in sugar content but also by an increase in invert sugar and soluble nitrogen.

Key words: sugarbeet, storage, differences between the genotypes, sugar losses

In den Jahren 2008/09 und 2009/10 wurden unter verschiedenen Lagerungsbedingungen in sechs Ländern mit 12 Zuckerrübengenotypen Lagerungsversuche durchgeführt. Die in Streifen angebauten Rüben wurden im September/November maschinell (entsprechend guter fachlicher Praxis) oder von Hand geerntet und in Säcken in Mieten oder in einzelnen Säcken/Behältern in Scheunen oder Klimaräumen eingelagert. Alle Proben wurden vor und nach der Lagerung gewogen und auf ihren Gehalt an Zucker (polarimetrisch), Kalium, Natrium, Amino-N, löslichem Gesamtstickstoff, Saccharose (HPLC), Glucose, Fructose, Raffinose, Betain und Glutamin untersucht. Nach der Lagerung wurden die Proben auch visuell begutachtet. Genotypische Unterschiede wurden für die Merkmale Wurzelspitzenbruch, Neuaustrieb, Schimmelbildung und Fäulnis beobachtet, obwohl die Unterschiede nicht in allen Versuchen einheitlich und länderabhängig waren. Die Zuckerverluste schwankten zwischen 0 und 66 % der Ausgangsmenge und schienen durch verschiedene biotische und abiotische Faktoren bedingt zu sein. Wurzelschädigungen durch maschinelle Ernte und Lagertemperatur waren Hauptfaktoren für die Zuckerverluste. Die Genotypen zeigten signifikante Unterschiede im Zuckerverlust, aber es gab starke Interaktionen mit den Faktoren Jahr und Ort. Korrelationen bestanden zwischen dem Zuckerverlust und Gehalt an Zucker (r = –0,66), Gehalt an Betain (r = –0.62) und Wurzelspitzenbruch (r = +0.66), und nach der Lagerung, Schimmelbildung (r = +0.87), Fäulnis (r = +0.88) und Invertzuckergehalt (r = +0.89).

Die Inhaltsstoffanalysen zeigten genotypische Unterschiede in der Abnahme der Rübenqualität nach der Lagerung, nicht allein in Bezug auf den Zuckergehalt, sondern auch in Bezug auf die Zunahme des Gehaltes an Invertzucker und löslichem Stickstoff.

Stichwörter: Zuckerrüben, Lagerung, genotypische Unterschiede, Zuckerverluste

1 Introduction

The reform of the sugar industry in Europe resulted in the closure of many sugar factories and extending of the sugarbeet campaign [1]. In most countries of North West Europe, beet processing continues until mid-January or later. However, harvesting has to be finished before frost damage may occur. This means that a part of the beet has to be stored for about two months or even longer. For this reason it is important to know which factors affect the sugar losses and the reduction in beet quality during long-term storage. Although much research has been done in the past [2–4] it is not fully understood what the effects of growing, harvesting and storage conditions are on the storability of different genotypes. A joint IIRB project was carried out to investigate the storability of sugarbeet under different conditions. The aim of the study was to estimate the impact of various factors during the growing, harvesting and storage on the storability of different genotypes and to define a standard procedure to test this storability.

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2 Materials and methods

2.1 Trial design

In 2008/09 and 2009/10 storage trials with 12 genotypes were carried out under different conditions in six countries. The genotypes were provided by KWS (4 types), SESVanderHave (4 types), Syngenta (2 types) and Maribo Seed (2 types).
The trials were carried out in Belgium, France, Germany, Sweden and the Netherlands and only in 2009/10 also in Austria.

2.2 Growing

The genotypes were grown in strips without replicates using local good agricultural practice. Data about location, soil type, pH value, fertilizer usage, preceding crops and irrigation were collected. During the growing season, observations were made on pests and diseases, drought, flood and frost. Table 1 shows the main characteristics of the trial fields for both years in the participating countries.

2.3 Harvesting

Harvesting was carried out both years between mid-September and mid-November either by machine, according to local practice, or by hand. IRBAB also did some storage with hand harvested beets that were additionally damaged by a turbine [5].
Reference samples were taken for the determination of the quality

Table 1: Characteristics of the trial fields in Germany (DE), Sweden (SE), The Netherlands (NL), Belgium (BE), France (FR) and Austria (AT)

Country	Longitude	Latitude	Soil type	Organic matter (%)	pH value	pH-solvent	Carried out by
			2008/09				
DE	9°52’	51°49’	loam	5.0	6.8	KCl	KWS
SE	13°11’	55°39’	clay	2.2	7.3	H_2O	NBR
NL	6°55’	52°52’	sand	19.2	4.9	KCl	IRS, PPO
FR	3°10’	49°30’	loam	1.5	8.2	H_2O	ITB
			2009/10				
DE	9°52’	51°42’	loam	5.0	7.0	KCl	KWS
SE	13°11’	55°39’	clay	2.4	7.5	H_2O	NBR
NL	6°55’	52°52’	sand	23.6	5.1	KCl	IRS, PPO
BE	5°04’	50°41’	loam	2.1	–	–	IRBAB
FR	2°59’	50°03’	loam	2.4	8.3	H_2O	ITB
AT	16°06’/16°47’	48°37’/48°09’	loam	2.8/3.0	7.5	$CaCl_2$	ZFT

Table 2: Characteristics of the storage trials in Germany (DE), Sweden (SE), The Netherlands (NL), Belgium (BE), France (FR) and Austria (AT)

Trial	Harvesting	Storage				Storage temperature (°C)				Humidity
		Type	Place	Start	Days	Average	Min	Max	Sum*	%
				2008/09						
DE a	hand	nets	climate	11 October	83	12	10	14	996	75–100
DE b	machine	nets	climate	11 October	83	12	10	14	996	75–100
SE	machine	bags	***	22 October	79	6.5	1.1	12.6	514	80–100
NL	machine	nets	clamp	04 November	70	5.7	1.9	11.9	339	90–96
BE a	hand	drums	climate	04 November	71	11.5	10.5	12	817	99
BE b	machine	drums	climate	04 November	71	11.5	10.5	12	817	99
BE c	hand	boxes	barn	04 November	73	6.5	0	13.5	472	<75
BE d	machine	boxes	barn	04 November	73	6.5	0	13.5	472	<75
FR a	machine	nets	climate	15 September	32	18	–**	–	576	100
FR b	machine	nets	climate	24 October	28	18	–	–	504	100
FR c	machine	nets	climate	24 October	35	13	–	–	455	100
				2009/10						
DE a	hand	nets	climate	09 November	80	9.7	7.6	10.8	776	68–100
DE b	machine	nets	climate	09 November	80	9.7	7.6	10.8	776	68–100
SE	machine	bags	***	26 October	70	9.3	2.0	12.0	651	60–100
NL a	hand	bags	barn	11 November	58	10.9	5.3	14.2	632	82–97
NL b	machine	bags	barn	11 November	58	10.9	5.3	14.2	632	82–97
NL c	machine	nets	clamp	11 November	58	6.8	1.7	12.7	394	93–97
BE a	hand +turbine	drums	climate	17 September	36	10.5	10.5	10.5	360	100
BE b	hand+turbine	drums	climate	17 September	36	15.5	15.5	15.5	540	100
BE c	machine	drums	climate	28 October	47	10.5	10.5	10.5	490	100
BE d	machine	drums	climate	28 October	47	15.5	15.5	15.5	720	100
BE e	machine	boxes	barn	28 October	89	8.3	2.0	14.6	720	–
FR a	machine	nets	climate	10 September	28	16.8	13	20	470	100
FR b	machine	nets	climate	15 October	26	16.8	13	20	437	93–100
AT a	machine	nets	cellar	7 October	60	10.2	8.3	11.8	612	93–100
AT b	machine	nets	cellar	7 October	102	8.3	3.6	11.8	847	93–100
AT c	machine	nets	cellar	8 October	59	10.2	8.3	11.8	602	93–100
AT d	machine	nets	cellar	8 October	101	8.3	3.6	11.8	838	93–100

* Sum = storage days × temperature. ** – not measured. *** outside and when necessary in the barn to avoid frost

before storage. Between the different trials the sample size varied from 10–60 kg and the number of replicates for each genotype from 2–4. Subsequently, samples of the same size were taken for storage.

2.4 Storage

Samples were stored either in nets inside a clamp or in nets, bags or boxes outside or in a barn, climate room or wine cave under different storage conditions (Table 2). All samples were weighed before and after storage. Temperature and humidity were registered. The number of replicates for each genotype varied from 1 to 6.

Fig. 1: Net samples placed in the clamp in The Netherlands

For the storage inside a clamp from each genotype three net samples of about 15 kg each were placed at six different positions in the clamp: in the center, at the top, and at both flanks in the middle and at the bottom (see Fig. 1).

The samples of each genotype were placed between two dumper loadings of the same genotype. The clamp was permanently covered with polypropylene fleece (TopTex) after two weeks of storage and additional incidental protection with plastic sheet during frost periods. In 2008/09 the average storage temperature was 5.7 °C with a minimum of 2 °C and a maximum of 12 °C. In 2009/10 the average was 6.8 °C with a minimum of 2 °C and a maximum of 13 °C. The storage period was 70 and 58 days respectively and a temperature sum (storage days · temperature) 399 and 394 °C · day.

The different types of nets, bags and boxes in combination with the storage outside, in a barn, climate room or wine cave are shown in Figure 2. Storage time varied from 26 to 102 days and a temperature sum from 350 to 1000 °C · days. Outside and in barns the ambient temperature fluctuated between 0 and 14 °C. Different temperatures were used in the climate rooms. The lowest average storage temperature was 8 °C and the highest 18 °C.

In Belgium respiration losses were determined in respiration drums (Fig. 3). In 2008/09 beet samples from the field trial in the Netherlands were used.

2.5 Observations after harvesting and storage

After harvesting the beet were examined visually for surface damage in Sweden as well as in Austria. All participants examined the beet for tip breakage after harvest or storage and for sprouts,

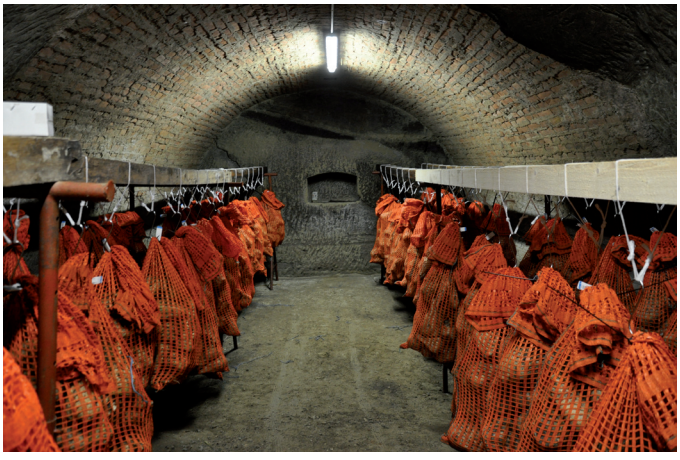

Fig. 2: Different storage experiments in Germany (top left), Sweden (top right), France (bottom left) and Austria (bottom right)

Fig. 3: Respiration drums in Belgium

moulds and rot after storage. Surface damage and root breakage was determined according to the IIRB protocol [5]. Numbers of sprouts were counted and sprout length was estimated. Total sprout length was calculated by multiplying the number of sprouts with the estimated length. For moulds and rot an infestation score from 0 (0% infestation) to 9 (100% infestation) was used.

2.6 Sample treatment and analyses

The reference samples after harvesting as well as the stored samples after storage were processed in the tarehouse of each participant without delay. After visual observations the washed beet were sawed and the homogeneous beet brei was immediately shock frozen and stored at below –20 °C. Frozen beet brei was transported and subsequently processed centrally in one laboratory, using a 0.3% (w/v) $Al_2(SO_4)_3$ solution for extraction and clarification. In the filtrates, sugar content was determined by polarimetry, potassium and sodium contents by flame photometry and amino nitrogen content by fluorimetry [6]. Sucrose, glucose, fructose, raffinose, betaine and glutamine contents were determined by HPLC [7] and total soluble nitrogen content by gas chromatography [8]. Sugar losses were calculated from mass and sugar content (by polarimetry) before and after storage.

2.7 Statistical evaluation

As only two years were included in this study the effects of year and location were not regarded separately but were combined as environments. Before a statistical evaluation of the genotype effects was carried out, the data of several trials were combined and averaged: from the 2008 trials BE-a,b,c,d and FR-a,b,c and from the 2009 trials BE-a,b, BE-c,d,e, AT-a,c and AT-b,d (for abbreviations see Table 2). Statistical analysis was carried out using the REML directive in the GENSTAT package.

3 Results and discussion

No large infestations of pests and diseases were observed, except violet rot in hand harvested beet in Germany in 2008. The results of these hand harvested beet are not included in the final statistical evaluation. Table 3 contains an overview of the important observations and analytical results after storage. The average of the 12 genotypes is presented for each storage trial. Large differences were observed between the different storage trials. This may be explained by the different storage conditions. Storage time, storage conditions (temperature, humidity and ventilation), beet damage, moulds and rot are related to the sugar losses. This is in agreement with previous observations [2–4].

In 2008/09, average net mass losses during storage varied from 2% in the clamp in the Netherlands to 11% in the machine harvested beet in Germany. In 2009/10, average net mass losses varied from 2% for machine harvested beet in Sweden up to 30% for machine harvested beet in Germany. Relatively high mass losses during storage were also measured in Austria (10 to 18%) and Bel-

Table 3: Average results of the 12 genotypes for each storage trial in Germany (DE). Sweden (SE), The Netherlands (NL), Belgium (BE), France (FR) and Austria (AT)

Trial	Root mass loss	Sugar losses total	Sugar losses per day	Surface damage	Tip losses	Sprouts total length	Moulds*	Rot*
	%	%	g/kg	cm^2/kg	g/kg	cm		
				2008/09				
DE a	9.6	13.2	1.6	–**	–	23.8	2.8	–
DE b	10.7	10.6	1.3	–	–	8.0	3.4	–
SE	3.7	7.7	1.0	2.6	14.9	0.5	2.3	1.4
NL	2.1	4.7	0.7	–	24.3	6.0	1.9	2.3
BE a	3.7	5.9	0.8	–	0.3	5.9	–	–
BE b	1.5	4.5	0.6	–	5.2	4.2	–	–
BE c	8.4	3.0	0.4	–	–	–	–	–
BE d	9.0	4.7	0.6	–	–	–	–	–
FR a	8.2	8.1	2.5	–	–	–	3.4	2.1
FR b	5.4	–	–	–	–	–	3.3	1.4
FR c	4.4	–	–	–	–	–	2.4	1.3
				2009/10				
DE a	18.1	4.0	0.5	0.0	1.4	7.7	1.7	–
DE b	29.9	5.1	0.6	10.0	2.9	0.0	2.6	–
SE	2.2	11.4	1.6	2.9	7.3	14.9	2.3	1.2
NL a	2.3	2.9	0.5	–	7.4	25.4	1.3	1.2
NL b	5.5	8.2	1.4	–	26.9	21.6	3.7	3.0
NL c	4.9	5.4	0.9	–	24.1	3.7	3.1	2.8
BE a	5.7	9.6	2.7	–	34.3	2.8	3.6	2.1
BE b	5.4	10.9	3.0	–	25.2	3.8	3.1	1.9
BE c	1.3	2.9	0.6	–	38.6	7.1	3.1	2.2
BE d	2.4	4.2	0.9	–	35.5	9.2	4.6	3.0
BE e	1.4	9.9	1.1	–	37.1	2.2	–	2.8
FR a	5.4	5.6	2.0	–	3.9	–	3.0	–
FR b	4.1	8.9	3.4	69.1	14.1	–	1.8	–
AT a	10.8	17.6	2.9	0.3	8.4	–	4.7	1.5
AT b	17.6	39.3	3.8	0.2	8.2	–	–	3.6
AT c	10.2	13.7	2.3	0.4	6.9	–	4.0	1.2
AT d	16.0	26.9	2.6	0.5	6.7	–	–	2.4

* Visual observation 0 to 9: 0 = 0% moulds/rot; 9 = 100% moulds/rot. ** – not measured

Table 4: Relative values for each genotype; 100 = average of all genotypes in each trial

Genotype	Sugar losses	Sugar content	Root mass loss	Surface damage	Tip losses	Sprouts total length	Moulds	Rot
a	82.3	102.5	101.1	76.6	101.1	194.4	86.4	82.6
b	86.0	102.1	92.7	123.7	88.7	177.2	91.9	99.4
c	88.2	98.7	94.8	70.7	84.6	133.0	93.0	97.9
d	91.1	101.2	99.7	90.2	82.6	128.3	87.4	102.1
e	95.8	97.7	102.0	95.0	120.7	60.7	96.4	95.1
f	97.1	103.6	103.1	93.6	94.9	33.9	88.8	89.3
g	97.3	101.9	93.5	97.4	82.9	73.0	97.8	92.7
h	99.4	99.7	98.1	136.8	89.8	52.9	110.1	98.7
i	105.2	98.8	105.5	115.1	115.3	137.7	103.9	100.8
j	107.5	98.6	98.8	84.7	115.0	49.4	110.2	104.9
k	109.5	98.6	94.0	99.9	94.5	88.0	112.7	107.9
l	140.9	96.6	114.9	117.6	129.8	71.3	121.5	129.0
LSD (5%)*	10.0	0.1	12.7	33.6	20.4	30.1	8.1	9.6
Correlation**	+1.00	–0.66	+0.68	+0.37	+0.66	–0.49	+0.87	+0.88

* LSD Least significant difference. ** Correlation with sugar losses.

gium in 2008/09 in the boxes (9%). These high mass losses may be explained by loss of water due to the use of nets with an open net structure or of open boxes. In Germany the mass losses were enhanced by high ventilation in combination with a relatively low humidity during a part of the trial period. In Belgium the humidity was relatively low in the room where the boxes were placed. In Austria the high sugar losses contributed considerably to the mass losses.

The storage of net samples in a clamp gives the best simulation of the normal storage conditions in practice. However, this method

Table 5: Average results of the 12 genotypes for some important quality parameters before and after storage for each trial

Trial	Sugar		Amino N		Soluble N		Sucrose		Invert sugar		Raffinose	
	%		mmol/kg		mmol/kg		%		%		%	
	before	after	before	after	before	after	before	after	before	after	before	after
						2008/09						
DE a	19.8	19.1	9.3	17.1	41.2	52.6	19.6	18.8	0.1	0.6	0.04	0.32
DE b	19.8	19.9	9.3	15.4	41.2	56.3	19.6	19.2	0.1	0.7	0.04	0.35
SE	19.6	18.8	6.4	7.7	26.3	32.8	19.5	18.7	0.1	0.8	0.05	0.29
NL	18.4	17.9	12.4	13.8	40.9	48.6	18.3	17.7	0.1	0.2	0.04	0.08
BE a	18.3	17.9	13.0	18.0	45.1	56.8	18.3	17.9	0.1	0.2	0.03	0.03
BE b	18.4	17.8	12.4	16.7	45.1	56.5	18.3	17.7	0.1	0.2	0.03	0.03
BE c	18.3	19.4	13.0	17.1	40.9	59.9	18.3	18.9	0.1	0.2	0.04	0.06
BE d	18.4	19.3	12.4	16.5	40.9	58.5	18.3	18.7	0.1	0.3	0.04	0.06
FR a	16.9	17.0	5.2	7.1	–*	–	–	–	–	–	–	–
FR b	–	19.7	–	8.4	–	–	–	–	–	–	–	–
FR c	–	19.1	–	8.5	–	–	–	–	–	–	–	–
						2009/10						
DE a	19.7	23.4	7.5	13.2	35.7	50.4	19.2	23.1	0.2	0.4	0.06	0.20
DE b	19.8	27.1	6.6	9.9	24.5	53.7	19.5	26.8	0.1	1.3	0.05	0.73
SE	19.8	18.0	7.0	9.0	35.0	39.1	19.6	17.7	0.2	1.0	0.06	0.16
NL a	18.7	18.6	8.9	12.6	31.2	39.5	18.6	18.3	0.1	0.2	0.03	0.07
NL b	18.3	17.8	8.2	10.3	30.1	39.1	18.1	17.7	0.1	0.5	0.04	0.12
NL c	18.3	18.2	8.2	8.4	30.1	35.3	18.1	18.1	0.1	0.4	0.04	0.10
BE a	19.6	18.8	7.9	11.1	36.2	42.3	19.3	18.3	0.1	0.5	0.06	0.06
BE b	19.6	18.5	7.9	11.6	36.2	43.4	19.3	19.9	0.1	0.3	0.06	0.09
BE c	20.5	20.0	6.7	9.8	37.7	49.7	20.4	19.4	0.2	0.5	0.06	0.08
BE d	20.5	19.5	6.7	9.9	37.7	35.4	20.4	19.0	0.2	0.7	0.06	0.19
BE e	20.5	19.1	6.7	7.5	37.7	43.3	20.4	18.6	0.2	0.4	0.06	0.05
FR a	18.9	18.9	4.6	7.6	–	–	–	–	–	–	–	–
FR b	20.4	19.4	9.2	12.9	35.3	43.2	20.7	20.3	0.1	0.2	0.04	0.04
AT a	19.3	17.8	10.1	9.0	34.8	42.5	19.2	17.3	0.2	1.7	0.05	0.27
AT b	19.3	14.3	10.1	7.2	34.8	45.3	19.2	12.7	0.2	5.6	0.05	0.50
AT c	17.5	16.8	15.0	15.8	44.7	52.1	17.7	16.2	0.2	1.1	0.04	0.21
AT d	17.5	15.2	15.0	12.7	44.7	50.7	17.7	13.4	0.2	3.4	0.04	0.50

* – beet samples were not analyzed

is time consuming and gives relatively high variations. A further disadvantage is the problem of recovering the complete net samples, without destroying the net, when the clamp is removed. If the beet samples are stored outside a clamp, too much dehydration should be avoided by using less ventilating bags or covered boxes instead of nets or open boxes.

Large differences were found between the trials for surface damage and to a lesser extent for tip losses. This might be explained by lack of standardization of the scoring.

In Table 4 the average relative results of each genotype are given for the same parameters as well as for the initial sugar content. For each trial the average result of the 12 genotypes is 100. The genotypes are ranked in increasing order of sugar losses from a to l.

Significant differences in sugar losses between genotypes were found. The initial sugar content of the genotypes showed a negative correlation with the sugar losses (r = –0.66). Sugar losses were positively correlated with moulds (r = +0.87) and rot (r = +0.88). Weaker correlations were found between sugar losses on one hand and tip losses (r = +0.66) and surface damage (r = +0.37). Total sprout length showed a slight negative correlation with sugar losses (r = –0.49). It might be that the reduction of sprouting is caused by deep topping of the beet, resulting in more cut surface susceptible for moulds. However, it was not investigated whether the sprouting was correlated with the method of topping. Another explanation might be that the reduction of sprouting is caused by moulds and that healthy beets had more sprouts.

Beet quality deteriorated remarkably during storage by the decrease of sugar content and the increase of invert sugar content (glucose + fructose) together with raffinose and nitrogen compounds in most trials. Differences were found between the trial conditions (Table 5) and the genotypes (Table 6 and 7). The increase of the sugar content in some trials may be explained by the high dehydration of the samples, as can be concluded from the increase of the dry matter content for all genotypes (Table 7). Only genotypes with relatively high sugar losses showed on average a decrease of the sugar content during storage. Expressed on dry matter basis, the average sugar content decreased during storage from 76% to 73%. Depending on the genotype, sucrose content determined by HPLC deviated from the sugar content determined by polarimetry. The average difference between sugar content (determined by polarization) and sucrose content before storage was 0.01% and after storage 0.13%.

The increase of invert sugar and raffinose contents strongly depends on the storage conditions (Table 5) and to a lesser extent to genotype (Table 6). The invert sugar content of the genotypes after storage showed a positive correlation with the sugar losses during storage (r = +0.89). Betaine as well as glutamine contents somewhat increased during storage (Table 7). Betaine content of the genotypes before storage was negatively correlated with the sugar losses during storage (r = –0.62).

Table 6: Average results of the trials for some important quality parameters before and after storage for each genotype

Genotype	Sugar %		Sucrose %		Invert sugar %		Raffinose %		Amino N mmol/kg	
	before	after	before	after	before	after	before	after	before	after
a	19.5	19.9	19.5	20.1	0.14	0.54	0.046	0.17	9.5	12.9
b	19.4	19.6	19.3	19.2	0.14	0.83	0.046	0.22	7.7	10.2
c	18.8	18.9	18.9	18.9	0.12	0.69	0.053	0.18	8.2	10.7
d	19.3	19.5	19.2	19.5	0.13	0.72	0.045	0.21	7.7	9.7
e	18.6	18.5	18.8	18.6	0.11	0.78	0.043	0.15	11.1	14.7
f	19.7	19.9	19.6	19.7	0.13	0.68	0.039	0.16	9.4	12.0
g	19.4	19.4	19.4	19.4	0.12	0.61	0.049	0.16	7.4	10.6
h	19.0	18.7	19.2	18.5	0.13	0.85	0.045	0.18	8.3	10.8
i	18.8	18.9	18.8	18.3	0.15	0.95	0.048	0.28	7.7	9.7
j	18.8	18.6	18.9	18.7	0.13	0.98	0.051	0.19	8.8	11.3
k	18.8	18.6	19.0	18.2	0.13	1.13	0.041	0.29	7.7	9.6
l	18.4	17.8	18.4	17.6	0.14	1.33	0.042	0.27	9.6	10.5
Average	19.0	19.0	19.0	18.9	0.13	0.84	0.046	0.20	8.6	11.1
LSD* (5%)	0.02	0.2	0.2	0.4	0.01	0.24	0.003	0.06	0.1	0.3
Correlation**	–0.65	–0.81	–0.71	–0.79	+0.23	+0.89	–0.31	+0.58	+0.17	–0.25

* LSD Least significant difference. ** Correlation with sugar losses.

Table 7: Average results of the trials for some additional parameters analysed before and after storage for each genotype.

Genotype	Dry substance %		Betaine mmol/kg		Glutamine mmol/kg		Soluble N mmol/kg	
	before	after	before	after	before	after	before	after
a	26.0	27.4	16.1	17.8	3.8	4.7	37.9	51.9
b	25.7	26.9	14.5	14.5	2.5	3.9	35.7	45.6
c	24.7	25.9	13.4	15.5	2.5	3.1	33.0	43.0
d	25.2	26.6	13.5	15.3	2.3	2.7	32.5	40.2
e	24.4	25.4	13.6	15.8	4.0	6.1	38.7	51.5
f	26.4	27.4	14.1	16.5	2.8	3.6	37.5	47.8
g	25.3	26.2	14.4	16.7	2.0	3.4	34.4	46.4
h	24.3	25.6	12.6	14.9	2.2	3.4	34.5	42.9
i	24.5	25.7	12.3	14.8	2.8	3.4	34.4	39.8
j	24.3	25.8	13.0	15.7	2.9	3.3	34.1	46.2
k	24.5	25.5	13.1	15.4	2.2	2.8	33.9	41.2
l	24.0	25.4	12.7	15.6	3.1	3.6	34.9	44.5
Average	24.9	26.1	13.6	15.7	2.7	3.7	35.1	45.1
LSD (5%)*	0.3	0.3	0.5	1.1	0.3	0.5	1.5	2.3
Correlation**	–0.63	–0.61	–0.62	–0.19	–0.03	–0.19	–0.18	–0.26

* LSD Least significant difference. ** Correlation with sugar losses.

4 Conclusions

Large variations in mass and sugar losses and beet quality after storage were observed. Storage losses were affected by the harvesting procedure (surface damage, root tip breakage, topping) and storage conditions (time, temperature, humidity, ventilation). Machine harvesting causes surface damage and root tip breakage, which may promote moulds and rot during storage, resulting in higher sugar losses and reduced quality. The formation of sprouts did not increase sugar losses during storage. On the contrary, sprouts and sugar losses showed an inverse relationship. This can probably be explained by the association

of high sprout numbers with high topping and healthy beet, although this was not determined. Between genotypes significant differences for sugar losses were found. The differences in storability between genotypes were related to moulds and rot forming during storage. A weak negative correlation was found between the initial sugar and betaine contents on one hand and the sugar losses of the genotypes on the other. Beet quality decreased during storage not only due to the lower sugar content after storage but also due to an increase in invert sugar, raffinose and soluble nitrogen contents. Sugar determination deviated somewhat from the real sucrose content determined by HPLC, especially after storage. Between the genotypes significant differences were found for the decrease in quality.

Storage trials to assess the differences in storability between genotypes can best be carried out in controlled environments and must have many replicates. Conditions during storage trials should preferably resemble those in clamps in practice. Extreme temperature and/or humidity affect storage losses and may influence the ranking in storability of genotypes. Special care should be taken to have all varieties uniformly topped.

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Facteurs influencant la conservation de différents génotypes de betteraves – Résultats d'une étude commune IIRB (Résume)

En 2008/09 et 2009/10 des essais de conservation avec 12 génotypes ont été menés dans différentes conditions dans 6 pays. Les génotypes ont été plantés en bandes et récoltés en septembre et novembre, soit avec une machine (en utilisant de bonnes pratiques agricoles), soit à la main. Les échantillons ont été stockés, soit dans des sacs incorporés au silo, soit dans des sacs séparés ou en containers rangés à l'intérieur d'un hangar ou d'une chambre climatisée. Tous les échantillons ont été pesés et analysés avant et après le stockage : la richesse (par polarisation), le potassium, le sodium, l'azote aminé, l'azote total soluble, le saccharose, le glucose, le fructose, le raffinose et la teneur en bétaine et en glutamine. Après le stockage, les échantillons ont également été examinés visuellement. Les pertes en sucres ont été calculées à partir du poids et de la richesse avant et après le stockage.

Des différences entre les génotypes ont été observées pour les casses des pointes, les repousses, les moisissures et les pourritures, mais ces différences n'étaient pas sans ambiguïté dans tous les essais et variaient entre les observations des différents pays. Les pertes en sucre variaient de 0 à 66% par rapport à la quantité initiale et semblent dues à des facteurs biotiques et abiotiques. Les blessures à la récolte et la température de stockage sont les facteurs dominants à l'origine des pertes en sucre. Les génotypes montrent aussi une différence significative au niveau des pertes en sucres, mais il existe une forte interaction avec l'année et les sites d'expérimentation. Des corrélations peuvent être trouvées entre les pertes en sucre et la richesse (r = –0.66), la teneur en bétaine (r = –0.62) et les casses des pointes des betteraves (r = +0.66) et après le stockage, les moisissures (r = +0.87), les pourritures (r = +0.88) et la teneur en sucre inverti (r = +0.89).

Les analyses chimiques montrent des différences entre les génotypes au niveau de la baisse de la qualité de la betterave après la récolte: une réduction de la richesse mais aussi une augmentation des sucres invertis et de l'azote soluble.

Factores de influencia sobre la capacidad de almacenamiento de distintos genotipos de remolachas azucareras – resultados de un proyecto de investigación del IIRB (Resumen)

En seis países y bajo distintas condiciones climáticas se llevaron a cabo en los años 2008/09 y 2009/10 ensayos de almacenamiento con 12 genotipos de remolachas azucareras. Se cultivaron los genotipos en fajas y se los cosechó en septiembre/noviembre o por máquina o a mano (según la eficacia en la práctica). Se almacenaron las muestras de la cosecha o en silos o en sacos/contenedores en una sala o en un cuarto con aire acondicionado. Antes y después del almacenamiento se pesaron todas las muestras y se determinaron los contenidos de azúcar (polarimétricamente), potasio, sodio, amino nitrógeno, nitrógeno soluble total, sacarosa, glucosa, fructosa, rafinosa, betaína y glutamina. Después del almacenamiento también se examinaron las muestras visualmente. Se calcularon las pérdidas de azúcar del peso y del contenido de azúcar antes y después del almacenamiento.

Se observaron diferencias entre los genotipos en lo que se refiere a roturas de las puntas radiculares, brotes nuevos, mohos y podredumbres – las diferencias no fueron uniformes ni en los ensayos ni en los seis países. Las pérdidas de azúcar variaron entre 0 y 66 % de la cantidad de partida y parecieron estar condicionados por distintos factores bióticos y abióticos. Los daños en las raíces principalmente fueron causados por la cosecha mecanizada y la temperatura de almacenamiento. Diferencias significantes se observaron en la pérdida de azúcar de los genotipos y hubo fuertes interacciones entre los factores año y emplazamiento. Correlaciones se observaron entre pérdida de azúcar y contenido de azúcar (r = –0,66), contenido de betaína (r = –0,62) y rotura de la punta radicular (r = +0,66) y después del almacenamiento y mohos (r = +0,87), podredumbres (r = +0,88) y contenido de azúcar invertido (r = +0,89). Los análisis de los componentes mostraron diferencias entre los genotipos a nivel de la reducción de la calidad después del almacenamiento, no sólo por la reducción de los contenidos de azúcar sino también por el aumento de azúcares invertidos y nitrógeno soluble.

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