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Ministry of Food, Agriculture and Fisheries
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Contents. Indholdsfortegnelse

Summary

The objectives were to study fodder beet concerning (1) the influence of harvest time on yield, chemical composition, digestibility and feeding value of tops and roots, (2) the relationship between the concentration of *in vitro* organic matter disappearance (IVOMD) and *in vivo* digestible organic matter (DOM), and between the concentration of gross energy (GE) and DOM and the concentration of *in vivo* digestible energy (DE), and (3) the difference between DE calculated on the basis of chemical composition of DOM and *in vivo* DE. The study was based on digestibility trials with sheep fed fodder beet tops and roots harvested from the end of September to the middle of November and also fed fodder beet roots stored for up to 153 days in clamps in the years 1992, 1993 and 1994.

The yield of tops peaked at the end of October. The chemical composition, digestibility and feeding value of tops was not affected by the time of harvest but varied from year to year. The yield of roots increased also from the end of September to the end of October. A delay of 7 days in lifting in relation to topping caused a loss of mainly sugar of 10% in periods with high air temperatures. Storage of roots in clamps resulted in a weekly loss by respiration of 2.7 g of dry matter (DM) kg^{-1} DM, and sugar made up *c.* 70% of the loss. The increase in yield of fodder beet roots with a delayed harvest time, and the loss of DM, organic matter and sugar by delayed lifting in relation to topping and storage had no or only a small influence on the beet quality, including GE, DOM, DE and concentration of feed units for cattle (FU_C).

Equations for DOM based on IVOMD were developed on the basis of the results for both fresh tops and fresh and stored roots, as an earlier equation overestimated DOM by 5.5 and 7.1%, respectively. Similarly, an equation for DE based on GE and DOM was developed for fresh tops. DE in roots was, however, not overestimated. DE predicted on the basis of the chemical composition of DOM in tops and roots overestimated DE by 3.5 and 2.0%, respectively.

Key words: Yield, chemical composition, digestibility, time of harvest, storage in clamps.

Resumé

Forsøg med fodersukkerroer blev gennemført ved Foulum i årene 1992-94 med det formål at belyse 1) høsttidspunktets indflydelse på udbytte, sammensætning, fordøjelighed og foderværdi af både top og roer, 2) relationen mellem indhold af *in vitro* opløseligt organisk stof (IVOS) og *in vivo* fordøjeligt organisk stof (FOS) samt mellem indhold af bruttoenergi (BEN) og FOS og indhold af *in vivo* fordøjelig energi (FEN) og 3) forskellen mellem FEN beregnet ud fra den kemiske sammensætning af FOS og *in vivo* FEN. Fordøjelighedsbestemmelser med får blev gennemført på frisk top og roer høstet i perioden fra slutningen af september til midten af november samt roer opbevaret i op til 153 døgn i kule.

Udbyttet af bederoetop toppede ved slutningen af oktober måned. Samtidig var roetoppens kemiske sammensætning, fordøjelighed og foderværdi uberørt af høsttidspunktet, men niveauet varierede fra år til år. Udbyttet af bederoer steg ligeledes til slutningen af oktober. En udsættelse af optagningen med 7 døgn i forhold til aftopning forårsagede et tab af hovedsagelig sukker på 10% i perioder med høj lufttemperatur. Opbevaring i kule resulterede i et ugentligt respirationstab på 2,7 g tørstof (TS) pr. kg TS, og sukker udgjorde ca. 70% af tabet. Det stigende udbytte ved udsat høst og tabet af TS ved udsat optagning i forhold til aftopning samt ved opbevaring havde ingen eller kun ringe indflydelse på roekvaliteten, herunder BEN, FOS, FEN og indhold af foderenheder for kvæg (FE_K).

På grundlag af forsøgsresultaterne blev der for frisk top og både friske og opbevarede roer udviklet ligninger for FOS baseret på IVOS, da tidligere benyttet ligning overvurderede FOS med henholdsvis 5,5 og 7,1%. For toppen blev der yderligere på grund af overvurdering udviklet en ligning for FEN baseret på BEN og FOS. FEN i roer blev derimod ikke fejlevurderet af tidligere ligning. FEN i både top og roer blev overvurderet ved beregning ud fra den kemiske sammensætning af FOS med henholdsvis 3,5 og 2,0%.

Nøgleord: Udbytte, kemisk sammensætning, fordøjelighed, høsttidspunkt, opbevaring i kule.

Introduction

Fodder beet (*Beta vulgaris* L.) is a high-yielding crop. Tops of fodder beet, which include crowns, yield 2 to 5 t dry matter (DM) ha^{-1} and roots of fodder beet yield 10 to 14 t DM ha^{-1} in Denmark (*Augustinussen*, 1974; *Jacobsen & Bentholm*, 1985) and Great Britain (*Roberts*, 1987).

The potential feed value of fodder beet tops is high, complementing roots well, with a higher concentration of fibre and protein, but lower energy and dry matter levels (*Carlisle*, 1985). The concentration of ash, which includes sand, varies between 120 and 440 g kg^{-1} DM in fresh tops, and the average concentration of crude protein (CP), crude fibre (CF), sugars, digestible organic matter (DOM) and digestible crude protein (DCP) are respectively: 200, 150, 150, 780 and 150 g kg^{-1} organic matter (OM) (*Becker & Nehring,* 1969; *Larsen & Hvidsten,* 1969; *Strudsholm & Nielsen,* 1991).

The composition of ash in roots varies from 70 to 175 g kg^{-1} DM and the average concentration of CP, CF, sugars, DOM and DCP are, respectively, 75, 63, 687, 889, and 37 g kg^{-1} OM (*Becker & Nehring,* 1969; *Burgstaller et al.*, 1982; *Larsen & Hvidsten,* 1969; *Strudsholm & Nielsen,* 1991). The daily allowance of fodder beet roots included in rations may make up to *c.* 7 kg DM per dairy cow (*Stensig et al.*, 1993).

DOM in roughage may be predicted from the laboratory determination of the quantity of OM that disappears *in vitro* as a substitute of *in vivo* digestibility (*Møller et al.*, 1989). The relationship between *in vitro* OM disappearance (IVOMD) and *in vivo* DOM has not been determined for tops and roots of fodder beet.

Digestible energy (DE) measured *in vivo* in different feeds may be predicted from (1) the gross energy (GE) and the *invivo* DOM (*Møller & Hvelplund*, 1993) or (2) the chemical composition of *in vivo* DOM (*Weisbjerg & Hvelplund*, 1991). The value of these methods for predicting the DE of fodder beet tops and roots has not previously been examined.

The objectives were to study (1) the composition, digestibility and feeding value of fodder beet tops at different times of harvest, and of fodder beet roots at different times of harvest and different times of storage, (2) the relationship between the concentration of IVOMD and that of *in vivo* DOM, and the relationship between the concentration of GE and DOM and that of *in vivo* DE, and (3) DE predicted from the chemical composition of *in vivo* DOM. The differences between *in vivo* DE and DE predicted from the concentration of GE and *in vivo* DOM or predicted from the chemical composition of *in vivo* DOM were studied. These differences are expressed in feed units for cattle (FU_C).

Materials and methods

Digestibility trials with sheep on 12 samples of fresh fodder beet tops, which included leaves, petioles, and crowns, and 24 samples of fresh fodder beet roots were carried out in connection with three harvest time experiments. The beets were topped four times in each experiment in the period from 27 September to 10 November. Each topping included two lifting times of 0 and 7 days after topping.

Digestibility trials with sheep using 12 samples of fodder beet roots were also carried out in connection with three storage experiments. Each experiment included two clamps with stored roots harvested *c.* 13 October and *c.* 10 November, respectively. Five samples were taken from the middle and seven samples from the end of the storage periods. The experiments were carried out in connection with the above-mentioned harvest time experiments

Table 1. Monthly precipitation and daily air temperature at Foulum
Månedlig nedbør og gennemsnitlig lufttemperatur ved Foulum

Year *År*	**May** *Maj*	**June** *Juni*	**July** *Juli*	**Aug.** *Aug.*	**Sep.** *Sep.*	**Oct.** *Okt.*
Precipitation, mm. *Nedbør, mm*						
1992	28	2	43	114	38	54
1993	7	10	127	93	84	72
1994	10	59	10	133	172	44
Air temperature, °C. *Lufttemperatur, °C*						
1992	12.5	16.7	16.5	14.8	12.2	5.7
1993	12.4	12.9	13.3	13.1	10.1	6.5
1994	10.5	12.2	18.8	16.1	11.7	7.4

The experiments were established in 1992, 1993 and 1994 on fine loamy sand (pH 6.0) at Foulum, 56° 30′ N latitude, 9° 35′ east longitude, elevation 54 m. Monthly precipitation and air temperature from 1 May to 31 October in the three years are shown in Table 1.

Crops

Fodder beet (cultivar Magnum) was sown late April with a row space of 62.5 cm in 1992, and 50 cm in 1993 and 1994. The yearly application was 108 kg N, 46 kg P and 202 kg K per ha in slurry on *c.* 13 April, and 42 kg N per ha in mineral fertilizer on *c.* 20 April.

The experimental plots that were topped measured 30 m^2. There were two replicates. Each plot was divided into two subplots of 15 m^2, constituting the plots for the lifting. The crops for digestibility trials and storage experiments were supplemented with crops grown in the same fields as the crops in the harvest time experiments. The roots in the storage experiments were stored at 4-6°C in unroofed clamps with a covering of straw and plastic film to protect from frost damage. Each clamp contained *c.* 6 t of fodder beet roots. The storage loss was calculated on the basis of four samples of 50 roots per clamp at the beginning of storage and three samples of 60 roots per clamp four to five times during the period of storage.

Digestibility trials

The digestibility trials with sheep were based on 12 samples of fodder beet tops and 36 samples of fodder beet roots. Each sample of tops and roots contained *c.* 75 and 65 kg DM, respectively. Three to four Leicester sheep were used per sample according to *Møller et al.* (1989). The age of the sheep varied between two and six years. The daily allowance of fodder beet tops and fodder beet roots was *c.* 580 and *c.* 600 g DM, respectively. The daily allowance of hay supplement was *c.* 350 g DM. Before feeding, chopped tops and chopped roots were stored at –20°C. Each digestibility trial lasted for two weeks, and all the feed was consumed. Faeces were collected in the last week of the trial and stored at –20 °C.

DE was calculated after measuring the energy concentration in fresh samples of fodder and in faeces by using a Leco AC 300 isothermal electronic bomb calorimeter (*Pedersen & Witt*, 1989). The *in vitro* disappearance of organic matter was estimated with two samples per digestibility trial according to *Tilley & Terry* (1963) and *Møller et al.* (1989). The two samples from each digestibility trial were used in two runs of *in vitro* tests, respectively. Standard samples with known IVOMD were included in each run to ensure an accurate estimation.

Calculations

The concentration of digestible ether extract (DEE) in tops and roots was based on table-value of 11 and -1.0 g kg^{-1} OM, respectively, and digestible carbohydrates (DCH) was calculated as DOM-(DCP+DEE). DE was predicted from the chemical composition of DOM by using the following equation according to *Weisbjerg & Hvelplund* (1992):

(1) $$DE\ (MJ\ kg^{-1}\ OM) = 24.237 \times DCP\ (kg\ kg^{-1}\ OM) + 34.116 \times DE\ (kg\ kg^{-1}\ OM) + 17.30 \times DCH\ (kg\ kg^{-1}\ OM) - 0.766 \times sugar\ (kg\ kg^{-1}\ OM).$$

The correction for sugar in equation (1) has to be performed, when the concentration of sugar in fodder beet roots exceeds 200 g kg^{-1} DM. Sugar was analysed in freeze-dried material (*Jacobsen*, 1981). DE was also predicted by using the concentration of GE and DOM, and the following equation of *Møller & Hvelplund* (1993):

(2) $$DE\ (MJ\ kg^{-1}\ OM) = -19.8 + 0.933 \times GE\ (MJ\ kg^{-1}\ OM) + 0.0207 \times DOM\ (g\ kg^{-1}\ OM).$$

Using the concentration IVOMD and the following equation of *Møller et al.* (1989) DOM was predicted:

(3) $$DOM\ (g\ kg^{-1}\ OM) = 41.0 + 0.959 \times IVOMD\ (g\ kg^{-1}\ OM).$$

The feeding value of fodder beet tops and fodder beet roots was calculated in feed units for cattle (FU_C) by using the concentration of DE and crude fibre (CF) and the following equation of *Weisbjerg & Hvelplund* (1992):

(4) $$FU_C\ kg^{-1}\ OM = 0.0989 \times DE\ (MJ\ kg^{-1}\ OM) - 0.347 \times CF\ (kg\ kg^{-1}\ OM) - K,$$
where
$$K = 0.369 + 0.0369 \times ash\ (g\ kg^{-1}\ DM)/(1000 - ash\ (g\ kg^{-1}\ DM)).$$

The respiration losses of DM, OM and sugar during storage in clamps were calculated as differences between the contents of DM, OM and sugar in roots before and after storage roots, respectively. The mean weights of roots before (690 ±66 g) and after (672 ±83 g) storage were considered to be equal, and the concentration of DM expressed in g kg^{-1} roots was corrected by using an equation for each clamp. The equations were based on the weight of healthy roots and the number of days of storage.

The statistical calculations were based upon the ANOVA procedure according to SAS (1985). In unbalanced treatments the calculation of the least significant difference (LSD) was based upon a harmonic mean of cell sizes.

Results

Harvest time

The chemical composition, digestibility and feeding value of the fodder beet tops varied between years, but there was no significant effect of harvesting time (Tables 2 and 3). The concentration of GE was almost similar in the 12 samples (19.2 ±0.1 MJ kg^{-1} OM).

Table 2. Composition of fodder beet tops as a mean of topping times and mean of years
Sammensætning af bederoetop i gennemsnit af aftopningstider og gennemsnit af år

	Ash *Aske*	CP[1] *RP[1]*	CF *TR*	NDF *NDF*	ADF *ADF*	IVOMD *IVOS*	GE *BEN*
	g kg^{-1} DM *g pr. kg TS*			g kg^{-1} OM *g pr. kg OS*			MJ kg^{-1} OM *MJ pr. kg OS*
29 Sept.	160	199	139	310	160	823	19.3
13 Oct.	152	190	135	318	157	817	19.2
27 Oct.	162	188	140	358	162	803	19.2
10 Nov.	165	189	135	326	162	810	19.1
LSD[2]	NS	NS	NS	NS	NS	NS	NS
1992	173	203	127	341	155	792	19.3
1993	144	172	157	349	181	811	19.0
1994	162	200	128	293	145	838	19.3
LSD	6	6	10	30	8	17	0.1

1 CP=crude protein, CF=crude fibre, NDF=neutral detergent fibre, ADF=acid detergent fibre, IVOMD=*in vitro* organic matter disappearance, GE=gross energy, DM=dry matter, and OM=organic matter. *RP=råprotein, TR=træstof, NDF=neutral detergent fiber, ADF=acid detergent fiber, IVOS=*in vitro *opløseligt organisk stof, BEN=bruttoenergi, TS=tørstof og OS=organisk stof*

2 Least significant difference ($p<0.05$) and NS=no significance. *Laveste signifikante difference (p<0,05) og NS=ingen signifikans*

The yield of fodder beet tops harvested between 29 September and 10 November varied between harvest times and especially between years (Table 4). The weight of fresh tops and the yield of DM, OM, CP, and FU_C were all highest in 1993 and lowest in 1992. The weight of fresh tops and the yield of DM, OM, CP, and FU_C increased during the period from the end of September to the end of October and decreased during the first half of November. The effect of harvesting time was only significant for the weight of fresh tops and CP, however.

Table 3. Digestibility (*in vivo)* and feeding value of fodder beet tops in mean of topping times and mean of years

Fordøjelighed (in vivo) *og foderværdi af bederoetop i gennemsnit af aftopningstider og gennemsnit af år*

	DOM[1] *FOS[1]*	DCP *FRP*	DCF *FTR*	DE[2] *FEN[2]*	FU_C *FE_k*
	-------------	g kg^{-1} OM *g pr. kg OS*	--------------	MJ kg^{-1} OM *MJ pr. kg OS*	kg^{-1} OM *pr. kg OS*
29 September	777	140	99.9	14.1	0.907
13 October	782	129	91.4	13.7	0.873
27 October	769	128	99.7	14.0	0.893
10 November	757	126	92.0	13.6	0.859
LSD	NS	NS	NS	NS	NS
1993	713	127	80.7	12.7	0.761
1994	767	117	104.4	13.8	0.875
1995	819	149	102.5	15.1	1.013
LSD	16	5	3.8	0.3	0.034

[1] DOM=digestible organic matter, DCP=digestible crude protein, DCF=digestible crude fibre, DE=digestible energy, FU_C=feed units for cattle, and OM=organic matter. *FOS=fordøjeligt organisk stof, FRP=fordøjeligt råprotein, FTR=fordøjeligt træstof, FEN=fordøjelig energi, FE_K=foderenheder for kvæg, og OS=organisk stof.*

[2] Metabolizable energy may be calculated as 0.82×DE. *Omsættelig energi kan beregnes som 0,82×FEN.*

Table 4. Yield of fodder beet tops in mean of topping times and mean of years

Udbytte af bederoetop i gennemsnit af aftopningstider og gennemsnit af år

	Tops *Top*	DM[1] *TS[1]*	OM *OS*	CP *RP*	FU_C *FE_K*
	----------------	t ha^{-1} *t pr. ha*	----------------	kg ha^{-1} *kg pr. ha*	1000 ha^{-1} *1000 pr. ha*
29 September	41.2	4.97	4.19	826	3.80
13 October	43.8	5.39	4.57	862	4.01
27 October	44.2	5.74	4.89	900	4.39
10 November	40.6	4.89	4.10	764	3.54
LSD	2.2	NS	NS	56	NS
1992	34.5	4.44	3.69	748	2.81
1993	52.6	6.40	5.46	935	4.79
1994	40.2	4.89	4.16	831	4.21
LSD	1.9	0.60	0.58	49	0.60

[1] DM=dry matter, OM=organic matter, CP=crude protein, and FU_C=feed units for cattle. *TS=tørstof, OS=organisk stof, RP=råprotein, og FE_K=foderenheder for kvæg.*

The composition, digestibility and feeding value were almost similar in the 24 samples of fodder beet roots. The mean concentrations were 51.3 ±11.2g ash kg^{-1} DM, 709 ±23 g sugar kg^{-1} OM, 17.2 ±0.1 MJ GE kg^{-1} OM, 893 ±23 g DOM kg^{-1} OM, 14.7 ±0.6 MJ kg^{-1} OM and 1.05 ±0.06 FU_C kg^{-1} OM. Twelve samples were from roots lifted just after topping and 12 samples from roots lifted six to seven days after topping.

The results from the roots lifted just after topping showed that harvest time had a significant effect on the fibre concentration (Tables 5 and 6), the fresh weight of roots, and the yield of DM, OM, CP, sugar and FU_C (Table 7). The fibre concentration decreased slightly with a delayed harvest, significant only for CF and ADF (Table 5), and the yield of roots increased until the end of October (Table 7).

Table 5. Composition of fodder beet roots lifted just after topping as a mean of topping times and mean of years and also composition of fodder beet roots lifted seven days after topping

Sammensætning af bederoer optaget lige efter aftopning i gennemsnit af aftopningstider og gennemsnit af år samt sammensætning af bederoer optaget syv døgn efter aftopning

	n	Ash *Aske*	CP[1] *RP*[1]	CF *TR*	NDF *NDF*	ADF *ADF*	Sugars *Sukker*	IVOMD *IVOS*	GE *BEN*
		g kg^{-1} DM *g pr. kg TS*	----------	----------	---------- **g kg^{-1} OM** *g pr. kg OS*	----------	----------	----------	**MJ kg^{-1} OM** *MJ pr. kg OS*
Roots lifted just after topping. *Roer optaget lige efter aftopning*									
29 September	3	50.7	65.5	57.3	101	62.7	708	951	17.2
13 October	3	51.5	63.8	54.2	101	61.7	716	941	17.2
27 October	3	47.5	62.3	54.0	91	58.5	708	947	17.2
10 November	3	49.6	63.1	54.6	93	58.2	711	951	17.1
LSD		NS	NS	2.3	NS	2.9	NS	NS	NS
1992	4	45.4	72.0	54.7	86	58.4	732	957	17.2
1993	4	57.4	55.3	54.4	109	61.8	691	927	17.2
1994	4	46.7	63.7	56.0	95	60.2	709	958	17.1
LSD		NS	3.9	NS	8	2.5	26	12	NS
Roots lifted 0 and 7 days after topping. *Roer optaget 0 og 7 døgn efter aftopning*									
a. Without loss of OM. *a. Uden tab af OS*									
0 days. *0 døgn*	7	50.4	64.5	55.1	96	60.7	715	948	17.2
7 days. *7 døgn*	7	52.4	54.7	56.9	103	61.2	713	945	17.2
LSD		NS	NS	NS	NS	NS	NS	NS	NS
b. With loss of OM. *b. Med tab af OS*									
0 days. *0 døgn*	5	49.0	62.5	54.9	97	59.3	704	947	17.2
7 days. *7 døgn*	5	53.4	66.0	57.1	109	62.5	698	938	17.3
LSD		NS	NS	NS	10	NS	NS	NS	NS

[1] CP=crude protein, CF=crude fibre, NDF=neutral detergent fibre, ADF=acid detergent fibre, IVOMD=*in vitro* organic matter disappearance, GE=gross energy, DM=dry matter, and OM=organic matter. *RP=råprotein, TR=træstof, NDF=neutral detergentfiber, ADF=acid detergent fiber, IVOS=*in vitro *opløseligt organisk stof, BEN=bruttoenergi. TS=tørstof og OS=organisk stof*

Table 6. Digestibility (*in vivo*) and feeding value of fodder beet roots lifted just after topping as a mean of topping times and mean of years and also digestibility (*in vivo*) and fodder value of fodder beet roots lifted seven days after topping

*Fordøjelighed (*in vivo*) og foderværdi af bederoer optaget lige efter aftopning i gennemsnit af aftopningstider og gennemsnit af år samt fordøjelighed (*in vivo*) og foderværdi af bederoer optaget syv døgn efter aftopning*

	n	**DOM**[1] *FOS*[1]	**DCP** *FRP*	**DCF** *FTR*	**DE**[2] *FEN*[2]	**FU_C** *FE_K*
		------------- **g kg^{-1} OM** ------------ *g pr. kg OS*			**MJ kg^{-1} OM** *MJ pr. kg OS*	**kg^{-1} OM** *pr. kg OS*
Roots lifted just after topping. *Roer optaget lige efter aftopning*						
29 September	3	902	28.3	40.2	14.8	1.06
13 October	3	889	24.6	33.8	14.6	1.03
27 October	3	900	25.4	35.4	14.9	1.06
10 November	3	898	27.8	34.7	14.8	1.06
LSD		NS	NS	NS	NS	NS
1992	4	900	32.9	39.2	14.8	1.06
1993	4	884	16.6	31.0	14.4	1.02
1994	4	907	29.6	37.6	15.1	1.09
LSD		NS	7.1	NS	0.5	0.06
Roots lifted 0 and seven days after topping. *Roer optaget 0 og 7 døgn efter aftopning*						
a. Without loss of OM. *a. Uden tab af OS*						
0 days. *0 døgn*	7	897	27.2	36.4	14.8	1.06
7 days. *7 døgn*	7	892	27.3	36.9	14.7	1.04
LSD		NS	NS	NS	NS	NS
b. With loss of OM. *b. Med tab af OS*						
0 days. *0 døgn*	5	897	25.6	35.4	14.7	1.05
7 days. *7 døgn*	5	887	25.8	34.9	14.6	1.04
LSD		NS	NS	NS	NS	NS

1 DOM=digestible organic matter, DCP=digestible crude protein, DCF=digestible crude fibre, DE= digestible energy, FU_C=feed units for cattle, and OM=organic matter. *FRP=fordøjeligt råprotein, FTR=fordøjeligt træstof, FEN=fordøjelig energi, FE_K=foderenheder for kvæg og OS=organisk stof,.*

2 Metabolizable energy may be calculated as 0.82×DE. *Omsættelig energi kan beregnes som 0,82× FEN.*

The 12 samples of roots lifted six to seven days after topping were compared with the 12 samples of roots lifted just after topping. Out of these 12 samples, seven showed no loss of OM by delayed lifting - group (a) and five cases had a loss of OM by delayed lifting - group (b). In general the effect of delayed lifting after topping was low.

There was no significant effect on the composition of the roots by delaying the time of lifting in group (a), while there was a positive significant effect on the concentration of NDF in group (b) (Table 5). There was no significant effect of delayed lifting on the digestibility and feeding value in the two groups (Table 6).

The effect of delayed lifting time on the fresh weight of roots in group (a) was significant and positive (*c.* 6%) (Table 7). The effect on the fresh weight of roots and the yield of DM and sugar in group (b) was, however, significant and negative (*c.* 5%). The weather conditions in the periods from topping to lifting were characterised by higher mean air temperatures, 6.3°C, and higher mean daily precipitation, 2.7 mm, in group (b) than the mean air temperature, 5.2°C, and the mean daily precipitation, 1.6 mm, in group (a).

Table 7. Yield of fodder beet roots lifted just after topping as a mean of topping times and mean of years and also yield of fodder beet roots lifted seven days after topping
Udbytte af bederoer optaget lige efter aftopning i gennemsnit af aftopningstider og gennemsnit af år samt udbytte af bederoer optaget syv døgn efter aftopning

	n	Roots *Roer*	DM[1] *TS*[1]	OM *OS*	Sugar *Sukker*	CP *RP*	FU_C FE_K
		$t\ ha^{-1}$ *t pr. ha*				$kg\ ha^{-1}$ *kg pr. ha*	$1000\ ha^{-1}$ *1000 pr. ha*
Roots lifted just after topping. *Roer optaget lige efter aftopning*							
29 September	3	49.6	9.4	9.0	6.36	586	9.5
13 October	3	49.8	9.8	9.4	6.75	595	9.8
27 October	3	55.0	11.1	10.6	7.50	649	11.3
10 November	3	55.3	10.9	10.5	7.46	658	11.1
LSD[2]		3.9	0.7	0.7	0.60	47	0.8
1992	4	44.1	8.5	8.2	5.97	588	8.6
1993	4	53.8	11.2	10.8	7.44	594	10.9
1994	4	59.5	11.7	10.8	7.64	684	11.7
LSD		3.4	0.6	0.6	0.52	41	0.6
Roots lifted 0 and 7 days after topping. *Roer optaget 0 og 7 døgn efter aftopning*							
a. Without loss of OM. *a. Uden tab af OS*							
0 days. *0 døgn*	7	52.5	10.2	9.8	7.03	628	10.4
7 days.*7 døgn*	7	55.5	10.5	10.1	7.19	648	10.9
LSD		2.9	NS	NS	NS	NS	NS
b. With loss of OM. *Med tab af OS*							
0 days. *9 døgn*	5	52.4	10.4	10.0	7.00	614	10.4
7 days. *7 døgn*	5	49.6	9.3	9.0	6.23	586	9.3
LSD		1.7	0.2	0.3	0.25	NS	NS

1 DM=dry matter, OM=organic matter, CP=crude protein, FU_C=feed units for cattle. *TS=tørstof, OS=organisk stof, RP=råprotein og FE_K=foderenheder for kvæg.*

The year to year variation was higher than the effect of treatment. The root yield was lower in 1992 than in 1993 and 1994 (Table 7), and the root quality in 1992 was characterised by a higher concentration of CP and sugar, and a lower concentration of fibre expressed as NDF and ADF (Table 5).

Storage

Fodder beet roots harvested in the middle of October and November were stored in two clamps, respectively. The period of storage lasted *c.* 152 days from early harvest and *c.* 132 days from late harvest, and the mean temperature in the clamps was *c.* 5°C (Table 8). The storage loss was based on 34 determinations with five to six determinations in each clamp during storage. The 12 samples of healthy roots from the storage periods were compared with six samples of fresh roots at harvest (Table 8).

Table 8. The period of storing fodder beet roots in clamps and the temperature as a mean ±standard deviation of each clamp in the storing period.
Opbevaringsperioden for bederoer i kuler og temperaturen i gennemsnit ±spredning af hver kule i opbevaringsperioden .

Date of harvest *Dato for høst*	Number of days in clamp *Antal døgn i kule*	Number of loss determinations *Antal tabsbestemmelser*	Number of digetibility trials *Antal fordøjelighedsbestemmelser*	Date of sampling for digestibility trials *Dato for udtagning af prøver til fordøjeligheds-bestemmelser*	Number of temperature measurements[1] *Antal temperaturmålinger*	Temperature in clamp °C *Temperatur i kule °C*
15 Oct 1992	151	6	1	25 Jan.	96	4.6±1.1
11 Nov 1992	124	5	2	25 Jan., 15 March	78	4.8±1.2
13 Oct 1993	152	6	2	24 Jan., 14 March	57	5.5±0.8
10 Nov 1993	146	6	3	24 Jan., 14 March, 5 April	55	5.7±1.0
12 Oct 1994	153	6	2	23 Jan., 13 March	58	5.6±1.7
9 Nov 1994	125	5	2	23 Jan., 13 March	47	5.3±1.5

[1] Three thermometers per measurement. *Tre termometre pr. måling.*

All stored roots were healthy in the winter of 1994/95, while 4% of the stored roots in the winters of 1992/93 and 1993/94 were slightly decomposed after *c.* 100 days of storage. The slightly decomposed roots from 1992/93 and 1993/94 had a higher mean weight than both the fresh roots and the healthy roots after storage (Table 9). The concentration of ash was higher and the concentration of sugar was lower in slightly decomposed roots compared with both fresh roots and healthy, stored roots.

Respiration losses of DM, OM and sugar in healthy, stored roots were determined five to six times in each clamp in all three years. The following equation was developed for respiration loss of DM in fodder beet roots:

(5) Loss by respiration, g kg^{-1} DM before storage = 2.72 × number of weeks in clamp ($n=34$, $s_Y=22.9$, $r^2=0.725^{***}$).

Table 9. Weight and composition of healthy and slightly decomposed fodder beet roots after storage in clamps from 103 to 154 days after harvest in contrast to the weight and composition of fresh fodder beet roots at harvest in 1992 and 1993

Vægt og sammensætning af sunde og letrådne bederoer efter opbevaring i kuler fra 103 til 154 døgn i kontrast til vægten og sammensætningen af friske bederoer ved høst i 1992 og 1993

	Weight g per fodder beet *Vægt g pr. roe*	**DM[1] g kg^{-1} roots** *TS[1] g pr. kg roer*	**Ash g kg^{-1} DM** *Aske g pr. kg TS*	**Sugars g kg^{-1} OM** *Sukker g pr. kg OS*	**GE MJ kg^{-1} OM** *BEN MJ pr. kg OS*
Fresh fodder beets at harvest. *Friske roer ved høst*	730	200	37.2	691	17.2
Fodder beets after storage. *Roer efter opbevaring*					
Healthy[2]. *Sunde[2]*	668	193	39.0	675	17.5
Slightly decomposed[3]. *Letrådne[3]*	891	186	44.1	643	17.5
LSD	057	NS	2.0	11	NS

1 DM=dry matter, OM=organic matter and GE=gross energy. *TS=tørstof, OS=organisk stof og BEN= bruttoenergi.*

2 96% of the roots. *96% af roerne.*

3 4% of the roots. *4% af roerne.*

Table 10. Composition of fodder beet roots harvested 13 October (n=3) and 10 November (n=3) and of fodder beet roots stored in clamps for up to 153 days from ca. 13 October (n=5) and up to 132 days from ca. 10 November (n=7). Foulum, 1992 to 1993, 1993 to 1994 and 1994 to 1995

Sammensætning af bederoer høstet den 13. oktober (n=3) og 10. november (n=3) samt af bederoer opbevaret i kuler indtil 153 døgn fra ca. den 13. oktober (n=5) og indtil 132 døgn fra ca. den 10. november (n=7). Foulum, 1992-93, 1993-94 og 1994-95

Storage *Opbevaring*	n	**Ash** *Aske*	**CP[1]** *RP[1]*	**CF** *TR*	**NDF** *NDF*	**ADF** *ADF*	**Sugar** *Sukker*	**IVOMD** *IVOS*	**GE** *BEN*
		g kg^{-1} DM *g pr. kg TS*	**g kg^{-1} OM** *g pr. kg OS*						**MJ kg^{-1} OM** *MJ pr. kg OS*
Before[2]. *Før[2]*	6	50.5	63.4	54.4	97	59.9	713	946	17.2
After. *Efter*	12	55.4	64.8	56.3	109	65.5	696	935	17.2
LSD		NS	NS	NS	6	NS	15	9	NS

1 CP=crude protein, CF=crude fibre, NDF=neutral detergent fibre, ADF=acid detergent fibre, IVOMD=*in vitro* organic matter disappearance, GE=gross energy, DM=dry matter, and OM=organic matter. *RP=råprotein, TR=træstof, NDF=neutral detergent fibre, ADF=acid detergent fibre, IVOS=*in vitro *opløseligt organisk stof, BEN=bruttoenergi, TS=tørstof og OS=organisk stof.*

2 Samples of roots before storage in clamps. See Table 5. *Prøver af bederoer før opbevaring i kuler. Se tabel 5.*

Equation (5) illustrates that the loss of DM by respiration in g kg^{-1} DM before storage increased from 0 g DM before storage to 60 g DM after storage in 22 weeks. The loss of OM and sugar by respiration was similar in the 34 determinations of loss (960 ±3 g OM kg^{-1} DM lost by respiration and 671 ±18 g sugar kg^{-1} OM lost by respiration).

The concentration of fibre increased by storage, significant for NDF, whereas the concentration of sugar and IVOMD decreased (Table 10). Storage had no significant influence on the digestibility and feeding value (Table 11).

Table 11. Digestibility *(in vivo)* and feeding value of fodder beet roots harvested 13 October (n=3) and 10 November (n=3), and of fodder beet roots stored in clamps for up to 153 days from ca. 13 October (n=5) and for up to 132 days from ca. 10 November (n=7). Foulum, 1992 to 1993, 1993 to 1994 and 1994 to 1995

*Fordøjelighed (*in vivo*) og foderværdi af bederoer høstet den 13. oktober (n=3) og den 10 november (n=3) samt af bederoer opbevaret i kuler indtil 153 døgn fra ca. den 13. oktober (n= 5) og indtil 132 døgn fra ca. den 10. november (n=7). Foulum, 1992-93, 1993-94 og 1994-95*

Storage *Opbevaring*	n	DOM[1] *FOS*[1]	DCP *FRP*	DCF *FTR*	DE[2] *FEN*[2]	FU_C *FE_K*
		g kg^{-1} OM *g pr. kg OS*			MJ kg^{-1} OM *MJ pr. kg OS*	kg^{-1} OM *pr. kg OS*
Before[3]. *Før*[3]	6	894	26.3	34.3	14.7	1.05
After. *Efter*	12	905	21.3	39.9	15.0	1.07
LSD		NS	NS	NS	NS	NS

1 DOM=digestible organic matter, DCP=digestible crude protein, DCF=digestible crude fibre, DE= digestible energy, FU_C=feed units for cattle, and OM=organic matter. *FRP=fordøjeligt råprotein, FTR=fordøjeligt træstof, FEN=fordøjelig energi, FE_K=foderenheder for kvæg og OS=organisk stof,*

2 Metabolizable energy may be calculated as 0.82×DE. *Omsættelig energi kan beregnes som 0,82× FEN.*

3 Samples of roots before storage in clamps. See Table 6. *Prøver af bederoer før opbevaring i kuler. Se tabel 6.*

Digestible organic matter

In Denmark, DOM in roughage is often predicted from the concentration of IVOMD by using equation (3). This equation overestimated the mean digestibility of OM in fresh fodder beet tops by 54.7 g kg^{-1} OM ($p<0.001$), or 7.1%, and in fresh and stored fodder beet roots by 49.5 g kg^{-1} OM ($p<0.001$), or 5.5%, compared with the *in vivo* measurement. The following two equations were developed for fresh fodder beet tops and fodder beet roots, respectively, by correcting equation (3) taking into account the above-mentioned mean overestimation:

(6) Fresh fodder beet tops

$$\text{DOM (g kg}^{-1}\text{ OM)} = -13.7 + 0.959\ \text{IVOMD (g kg}^{-1}\text{ OM)}$$

(7) Fresh and stored fodder beet roots

$$\text{DOM (g kg}^{-1}\text{ OM)} = -8.56 + 0.959 \times \text{IVOMD (g kg}^{-1}\text{ OM)}.$$

Digestible energy

DE in fodder beet is often predicted from the chemical composition by using equation (1). This equation overestimated the mean DE in fresh tops by 0.50 MJ kg^{-1} OM ($p<0.001$), or 3.5%, and the mean DE in fresh and stored roots by 0.36 MJ kg^{-1} OM ($p<0.001$), or 2.0%, compared with the *in vivo* measurements. The mean feeding value based on predicted DE and calculated from equation (4) was overestimated in fresh beet tops by 0.049 FU_C kg^{-1} OM ($p<0.001$), or 5.6 %, and in fresh and stored beet roots by 0.036 FU_C kg^{-1} OM ($p<0.001$), or 3.4%, compared with the *in vivo* measurements.

DE in fodder beet was also predicted from the concentration of GE and DOM by using equation (2). In this study the equation overestimated the mean DE in fresh tops by 0.13 MJ kg^{-1} OM ($p<0.05$), or 0.9%, and the mean DE in fresh and stored roots by 0.006 MJ kg^{-1} OM (no significance), or 0.04%, compared with the *in vivo* measurements. The following equation was developed for fresh tops by correcting equation (2) in relation to the above-mentioned mean overestimation:

(7) Fresh fodder beet tops

$$\text{DE (MJ kg}^{-1}\text{ OM)} = -19.93 + 0.933 \times \text{GE (MJ kg}^{-1}\text{ OM)} + 0.0207 \times \text{DOM (g kg}^{-1}\text{ OM)}$$

Discussion

Fodder beet tops

The chemical composition, digestibility and feeding value of fresh fodder beet tops varied between years but not between harvest times. This is in contrast to most other roughage in which quality is reduced with a late harvest. The constant quality of fodder beet top can be due to a fast senescence and disappearance of the leaves. No references on this aspect have been found, however. The concentrations of ash, CP, CF, and DCP in fodder beet tops were nearly at the same levels as reported in "Feed Table 1995" (*Strudsholm et al.,* 1995).

Fodder beet tops differed from the first cut of perennial ryegrass, red clover and white clover by having a lower mean concentration of fibre expressed as CF, NDF and ADF (Table 12). However, the mean concentration of hemicellulose calculated as NDF–ADF was nearly identical in fodder beet tops and in red clover, whereas it was higher in perennial ryegrass and lower in white clover. This indicates that the lower fibre concentration in fodder beet tops is primarily caused by a lower concentration of cellulose and lignin (ADF). The mean concentrations of GE, DE and FU_C were higher in the three above-mentioned grassland crops than in fodder beet tops.

Table 12. Composition, digestibility *(in vivo)* and feeding value. Tops (n= 12) and roots (n=24) from fodder beet (*Beta vulgaris* L.) in contrast to perennial ryegrass (*Lolium perenne* L.) (n=14), red clover (*Trifolium pratense* L.) (n=11) and white clover (*Trifolium repens* L.) (n=6) at the first cut, whole crop winter wheat (*Triticum aestivum* L.) harvested 5 weeks after ear emergence (n=11), and whole crop maize (*Zea mays* L.) (n=3)

Sammensætning, fordøjelighed (in vivo) *og foderværdi. Top (n=12) og rod (n=24) af fodersukkeroer (*Beta vulgaris *L.) i kontrast til almindelig rajgræs* (Lolium perenne *L.) (n=14), rødkløver (*Trifolium pratense *L.) (n=11) og hvidkløver (*Trifolium repens *L.) (n=6) ved første slæt, helsæd af vinterhvede (*Triticum aestivum *L.) høstet 5 uger efter begyndende skridning (n=11) og helsæd af majs (*Zea mays *L.) (n=3)*

Species *Art*	**Ash** *Aske*	**CP**[1] *RP*[1]	**CF** *TR*	**NDF** *NDF*	**ADF** *ADF*	**DOM** *FOS*	**DCP** *FRP*	**GE** *BEN*	**DE**[2] *FEN*[2]	**FU_C** *FE_K*
	$g\ kg^{-1}$ DM *g pr. kg TS*			**$g\ kg^{-1}$ OM** *g pr. kg OS*				**$MJ\ kg^{-1}$ OM** *MJ pr. kg OS*		**kg^{-1} OM** *pr. kg OS*
Tops. *Roetop*	160	191	137	328	160	766	131	19.2	13.9	0.88
P. ryegrass[3]. *Alm. rajgræs*[3]	106	192	289	590	330	767	149	20.5	15.1	0.97
Red clover[3]. *Rødkløver*[3]	106	213	232	463	309	764	157	20.1	14.6	0.95
White clover[3]. *Hvidkløver*[3]	122	276	191	398	274	820	227	21.4	16.7	1.16
Roots. *Bederoer*	51	64	56	101	61	893	27	17.2	14.7	1.05
Maize[4]. *Majs*[4]	41	82	227	-	-	729	40	19.0	13.1	0.83
W. wheat[5]. *Vinterhvede*[5]	36	72	247	440	263	696	36	19.9	13.3	0.85

1 CP=crude protein, CF=fibre, NDF=neutral detergent fibre, ADF=acid detergent fibre, DOM=digestible organic matter, DCP=digestible crude protein, GE=gross energy, DE=digestible energy, FU_C=feed units for cattle, DM=dry matter, and OM=organic matter,. *RP=råprotein, TR=træstof, NDF=neutral detergent fibre, ADF=acid detergent fibre, FOS=fordøjeligt organisk stof, FRP= fordøjeligt råprotein, BEN=bruttoenergi, FEN=fordøjelig energi, FE_K=foderenheder for kvæg, TS= tørstof og OS=organisk stof,*

2 Metabolizable energy may be calculated as 0.82×DE. *Omsættelig energi kan beregnes som 0,82× FEN.*

3 *Møller & Hvelplund, 1991.*

4 Unpublished data. *Upublicerede data.*

5 *Møller & Hvelplund, 1993.*

The yield of fodder beet tops increased with a harvest delayed from the end of September to the end of October and decreased with the late harvest in November, but the effect of harvesting time was significant only for the weight of fresh tops and yield of CP. *Augustinus-*

sen (1974), *Jacobsen & Bentholm* (1985), and *Martin & Drewitt* (1984) found that the yield of tops declined as harvest was delayed in the autumn.

The yield of fodder beet tops was highest in 1993 and lowest in 1992. It is assumed that drought in June and the first weeks of July may have caused the lower yield in 1992. The higher digestibility and feeding value of fodder beet tops in 1994 than in 1992 and 1993 could be due to a late seasonal growth, as the first half of the growing season was very dry and the later half was wet

Fodder beet roots

The yield of fodder beet roots increased from the end of September to the end of October, which indicates that fodder beets produced reserves until the end of October. Other results have also showed that the yield of roots increased as harvesting was delayed in the autumn (*Augustinussen,* 1974; *Jacobsen & Bentholm,* 1986; *Martin & Drewitt,* 1984). The yield of fodder beet roots was higher in 1993 and 1994 than in 1992. It is assumed that drought in June and the first weeks of July caused the lower yield in 1992.

Delaying lifting by six to seven days after topping resulted in an increase of root fresh weight of *c.* 6% as a mean of cases without loss of OM, and a decrease of *c.* 5% as a mean of cases with loss of OM in the periods between topping and lifting. The fresh weight increased in the period between topping and lifting when precipitation was higher. The increase can be due to water uptake, as shown by *Christensen & Pedersen* (1966), who found that the fresh weight of sugar beet roots increased by 2.5% with an uptake of water when the lifting was delayed by five days.

In cases with loss of OM in the time from topping to lifting, the yields of DM, OM and sugar were reduced by *c.* 10%, whereas there were, as expected, no changes in these yields in cases without loss of OM with a delayed lifting. The air temperature in the periods from topping to lifting was higher in the cases with loss of OM, and higher respiration may be the reason for this loss. In a study by *Christensen & Pedersen* (1966) sugar beet roots showed the same trend as observed for fodder beet roots in this study. In accordance with this, *Christensen & Pedersen* found the greatest reduction in the yield of sugar beet roots by delayed lifting when air temperatures were highest,.in early autumn.

The weekly loss of DM by respiration in roots stored in clamps at *c.* 5°C was 2.7 g kg^{-1} DM. The loss of sugar made up *c.* 70% of DM lost by respiration. Other results (*Augustinussen,* 1976) show a slightly higher weekly loss of DM by respiration of *c.* 3.3 g kg^{-1} DM in fodder beet roots stored at *c.* 5°C.

Harvest time, number of days from topping to lifting, and storage all had either no or only little influence on the concentrations of GE, DOM, DE and FU_C in fodder beet roots. Probably this is due to the fact that the concentration of sugar was nearly the same at lifting just after topping (710 g kg^{-1} OM), at delayed time of lifting (706 g kg^{-1} OM), and after storage (696 g kg^{-1} OM). Further, sugar made up approximately the same concentration at respiration loss; 777 g kg^{-1} lost OM at delayed lifting in relation to topping and 671 g kg^{-1} lost OM at storage. Only the fibre concentration tended to decrease during the autumn and increase during storage.

Especially roots from fodder beet differed from whole crop maize and whole crop winter wheat by having a considerably lower mean concentration of fibre expressed as CF, NDF and ADF (Table 12). The mean concentrations of DE and FU_C in fodder beet roots were higher than in whole crop maize and whole crop winter wheat.

Digestible organic matter and energy

Calculation of DOM on the basis of IVOMD in fodder beet resulted in a mean overestimation of 7.5% for fresh tops and 5.5% for fresh and stored roots compared with *in vivo* DOM. The deviation in DOM calculated from *in vivo* DOM is also known from fresh fodder galega (*Galega orientalis* Lam.) (*Møller & Hostrup*, 1996). *Roberts* (1987) mentioned that *in vivo* evaluations of fodder beet roots indicated that *in vitro* analyses might overestimate the concentration of metabolisable energy of beet roots.

Calculation of DE on the basis of the chemical composition DOM in fodder beets resulted in a mean overestimation of 3.5% for fresh tops and 2.0% for fresh and stored roots compared with *in vivo* DE. The deviation in DE calculated from *in vivo* DE is a problem well-known with roughage of different kinds, especially silage (*Møller & Hvelplund*, 1993). The mean deviation was smaller in fresh beet tops and fresh and stored beet roots than the above-mentioned mean deviation in silage. *Pedersen et al.* (1989) mentioned that a high content of ash with a high concentration of carbonate might underestimate OM by 2-4% of DM, corresponding to 5-6% of predicted DE. *Pedersen et al.* also mentioned that the use of table-values for DEE might involve an error. This error is lower than ±2% of the predicted DE. Further, *Pedersen et al.* also mentioned that the factor used for digestible carbohydrates overestimates the energy of monosaccharides and di- and polycarbon acids. Generally this factor overestimates the predicted DE by only *c.* 4%, as it is unusual for DOM to contain more than *c.* 30% of monosaccharides, but the concentration of oxalic acid in beet tops is considerable. The concentration of oxalic acid in beet tops is *c.* 25 g kg^{-1} DM and higher during periods of drought at *c.* 45 g kg^{-1} DM (*Becker & Nehring*, 1969).

Strudsholm et al. (1995) predicted DOM from IVOMD by using equation (3) and DE from the chemical composition of DOM by using equation (1) and tabulated the predicted values in "Feed Table 1995". The table-values of DOM, DE and FU_C in fresh beet tops were higher than those found in this study. These deviations may be explained by the above-mentioned two deviations between calculated values and *in vivo* values of DOM and DE, respectively. The value of DOM in fresh and stored beet roots tabulated in "Feed Table 1995" was equal to the concentration of DOM in this study, and the table-values of DE and FU_C were higher than those found in this study, while the table-values of ash, CP, CF, and sugar were nearly equal to the concentrations found in this study. These deviations between the table-values of DOM, DE and FU_C in beet roots and the concentrations of DOM, DE and FU_C in this study may be explained by the above-mentioned two deviations between calculated and *in vivo* values of DOM and DE, respectively.

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