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Comparison of a high-input *vs* low-input system for Icelandic sheep production

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SUMMARY

A four-year experiment was carried out, comparing a high-input (H) system and a low-input (L) system for sheep production under Icelandic conditions. The main aim of the experiment was to find out if there was enough difference in production levels between the two systems to justify the differences in inputs. System H: The ewes were kept in a shed with slatted floors, during the whole feeding period, starting in late November and ending in late May. The ewes were shorn in the end of February/beginning of March all the years, and lambing took place in the second week of May. System L: The ewes were fed from December to late May in a shed with bedding, and with access to a lowland mire pasture. The ewes lambed in the last week of May and were shorn in the beginning of July.

The total feed energy intake from hay and supplements in the L system was only 53–71% of the H system. This difference was due to both fewer feeding days and a lower intake per day. The pasture seemed to have served as a considerable source of energy for the L system ewes. The L system ewes had significantly lower live weights than the H system ewes in the week of mating in Years 2 and 4, of 6.4 ($P<0.001$) and 1.8 ($P<0.05$) kg respectively, but differences in this respect were not significant in Years 1 and 3. Differences in lambing rates between systems were not significant among any of the experimental years. The ewe live weights after three months of pregnancy were significantly ($P<0.01$) higher (4–8 kg) in the H system than in the L system, except in Year 4. No significant differences were found in lamb birth weights, except in Year 4, when the L system gave slightly higher birth weights. The growth rates of the lambs calculated over all years were slightly higher in the L system.

It is concluded that under the climatic conditions of the 4-year experiment, it was possible to reduce both feed and housing costs considerably by using the L system compared to the H system, without depressing lambing performance or lamb growth. In addition, further savings of labour was apparent as a result of outdoor lambing. Wool prices will generally be lower in the L system, and to obtain the same carcass weights, additional costs of autumn grazing will be needed in the L system. The total effect seems economically positive for the L system. However, production systems with autumn shearing are nowadays under most circumstances more profitable than those tested in the present experiments.

Key words: feed costs, high-input, housing costs, lambing performance, lambing time, low-input, production systems, shearing time, sheep.

YFIRLIT

Samanburður á háaðfanga- og lágaðfangaframleiðslukerfi í sauðfjárrækt

Hér segir frá niðurstöðum fjögurra ára tilraunar þar sem borin voru saman tvö framleiðslukerfi fyrir íslenska sauðfjárrækt, hér nefnd háaðfanga (H)- og lágaðfanga (L)-kerfi. Megintilgangur tilraunanna var að finna út hvort nægur munur væri í afurðatekjum milli kerfanna tveggja til að réttlæta þann mun sem var á tilkostnaði. Kerfi H: Ærnar voru hafðar í húsum með grindagólfi allt fóðrunartímabilið, eða frá því síðari hluta nóvember til maíloka. Ærnar voru rúnar í febrúarlok/marsbyrjun ár hvert og báru flestar í annarri viku af maí. Kerfi L: Ærnar voru fóðraðar frá því í desember til maíloka í taðhúsum, gengu við opið og höfðu aðgang að láglendismýri. Ærnar báru í síðustu viku maí og voru rúnar í júlíbyrjun.

Heildarfóðurát í L-kerfinu reyndist aðeins 53–71% af því sem gerðist í H-kerfinu. Þetta kom bæði til af færri fóðrunardögum og minna áts á dag. Svo virðist sem töluvert hafi munað um framlag beitarinnar hjá L-ánum. L-ærnar voru marktækt léttari en H-ærnar í fangviku tvö áranna, og munaði þar 6,4 kg tilraunaár 2 og 1,8 kg tilraunaár 4. Hin árin var ekki marktækur munur milli kerfa á þunga ánna í fangviku. Munur á frjósemi milli kerfa var ekki marktækur neitt áranna, þó að í því efni hafi komið fram nokkur tilhneiging L-ánum í óhag á tilraunaári 2. Þungi ánna eftir þrjá mánuði meðgöngu var marktækt meiri (4–8 kg) í H-kerfinu öll árin nema það síðasta. Ekki fannst þó munur milli kerfa á fæðingarþunga lamba, nema hvað hann var örlítið hærri í L-kerfinu síðasta tilraunaárið. Vaxtarhraði lamba, litið yfir öll árin í heild, var lítillega meiri í L-kerfinu.

Niðurstaðan er sú að við þær aðstæður er tilraunin var gerð er unnt að draga verulega úr fóður-, húsvistar- og vinnukostnaði með því að nota L-kerfið í stað H-kerfisins, án þess að draga þurfi úr frjósemi, fæðingarþunga eða vaxtarhraða lamba. Tekjur af ull verða aftur á móti lægri í L-kerfinu, og til að ná sama fallþunga þar og í H-kerfinu þarf að kosta nokkru til við haustbeit, vegna þess að lömbin eru síðar fædd. Heildarútkoman virðist fjárhagslega jákvæð fyrir L-kerfið. Flest bendir þó til að framleiðslukerfi er miðast við haustrúning komi við núverandi aðstæður betur út en bæði þau kerfi er hér voru reynd.

INTRODUCTION

In Icelandic sheep production, most of the income is from meat produced by lambs grazing natural pastures in the summer. On the other hand, most of the production costs can be related to the feeding and management of the breeding stock in the winter. The main aim of good winter feeding and management of the ewes is to insure high lambing rates and good lamb growth. In a number of Icelandic sheep feeding trials reviewed by Thorsteinsson and Thorgeirsson (1989) it was shown that good body conditions of ewes at mating is a major prerequisite to insure high lambing rates. It is also emphasised in this review that high level of nutrition during late pregnancy and in the first weeks after lambing is vital for lamb growth, through its effects on lamb birth weights and ewe milking capacity, but that during the first 100 days of pregnancy ewes can be fed at or even slightly below maintenance without depressing productivity.

The indoor feeding period of adult ewes in Iceland is generally at minimum six months, i.e. from late November to late May, but in some regions and years over seven months. The fact that periods when high feeding levels are required are in most cases less than half of the indoor feeding period, offers some flexibility in designing production systems. In addition to feeding strategy, shed types, housing time, lambing time, shearing time, slaughtering time, grazing practices and some more factors can be varied.

The present experiment was designed to compare two production systems, which here will be referred to as the high-input (H) and the low-input (L) systems. Differences in inputs into the two systems, in terms of housing, feeding and labour costs, were obtained by varying shed types, supplementary feeding, housing time, shearing time and lambing time. The main aim of the experiment was to find out if there was enough difference in production levels between the two systems to justify the differences in inputs.

MATERIALS AND METHODS

Experimental design

The experiment was carried out in four production years, 1986–87, 1987–88, 1989–90 and 1990–91, each production year beginning and ending in the autumn (October). Table

Table 1. The experimental design.
1. tafla. Skipulag tilraunarinnar.

System *Kerfi*	Feeding starts *Fóðrun byrjar*	Lambing time *Sauðburður*	Shearing time *Rúningstími*	Floor type *Gólfgerð*	Rearing system *Húsvist*
High-input (H) *Há-aðfanga-*	Late November *S.hl. nóvember*	2nd week of May *Önnur vika maí*	February/March *Febrúar/mars*	Slatted floor *Grindagólf*	Kept indoors *Alger innistaða*
Low-input (L) *Lág-aðfanga-*	December *Desember*	Last week of May *Síðasta vika maí*	July *Júlí*	Bedded floor *Taðgólf*	Free to go outside *Ganga við opið*

1 gives an overview of the experimental design.

Animals

Each year 72 ewes of the native Icelandic sheep breed were used. The ewes were in two groups of 36 each and attempts were made to have the groups as equal as possible with respect to age, initial body weight and condition score. One group was kept under System H, and the other group under System L.

Feed

All ewes were fed the same hay *ad libitum* in both systems. Three types of supplements were fed: fish meal (90% DM, 600 g CP/kg DM, 1.00 FFU/kg DM), concentrates (90% DM, 180 g CP/kg DM, 1.00 FFU/kg DM) and grass pellets (90% DM, 140 g CP/kg DM, 0.80 FFU/kg DM). The amount of each supplement fed in various periods and years in the two systems can be seen in Table 2. Principally the idea was to use the supplements to: (1) ensure good nutritional status at mating in both systems, followed up with some supplementation in the very early mating in system H but not in system L; (2) support foetal growth and milking capacity in system H by supplementation in the late pregnancy and in the feeding days after lambing, whereas it was assumed that the access to new grass would fulfill these needs in the L system. As the hay quality was unusually low in Year 3, both groups received extra supplementation the whole winter.

Housing and management

System H: The ewes were kept in an insulated shed with slatted floors, from late November (21-Nov-86, 30-Nov-87, 23-Nov-89 and 23-Nov-90) until approx. one week after lambing, depending on number of lambs born per ewe, weather and pasture conditions, etc. The ewes were synchronised by hormones so the mating took place in 2–3 days (starting 14-Dec-86, 16-Dec-87, 16-Dec-89 and 17-Dec-90) and lambing mostly took place in the second week of May. In the shed there was a mechanical exhaust fan that was regulated by a thermostat so if the temperature inside went below certain limits (3°C before shearing and 10°C after shearing) the fan stopped. The ewes were shorn in the end of February/beginning of March.

System L: The ewes were fed in an insulated shed with bedding, and without any mechanical ventilation. The ewes also had access to a lowland mire pasture. The feeding period started in December, varying with respect to weather and pasture conditions (03-Dec-86, 28-Dec-87, 18-Dec-89 and 5-Dec-90). The ewes were synchronised by hormones so the mating took place in 2–3 days (starting 2-Jan-87, 7-Jan-88, 8-Jan-90 and 10-Jan-91) and lambing mostly took place in the last week of May. Ewes were fed indoors at maximum one week after lambing, depending on number of lambs born per ewe, weather and pasture conditions, etc. The ewes were shorn in the beginning of July.

After the end of indoor feeding the ewes in both systems were kept on a mixed lowland mire and cultivated grassland until beginning of July. Then all sheep were moved to a highland pasture, for grazing until approx. September 20.

Table 2. Supplements fed (kg/ewe) in the high (H) and low (L) input systems in various periods and years of the experiment.
2. tafla. Fóðurbætisnotkun (kg/kind) í kerfum H og L eftir árum og tilraunatímabilum.

Year *Ár*	Period *Tímabil*	H-system—*H-kerfi* Fish meal *Fiski-mjöl*	 Conc-entrates *Fóður-blöndur*	 Grass pellets *Gras-kögglar*	L-system—*L-kerfi* Fish meal *Fiski-mjöl*	 Conc-centrates *Fóður-blöndur*	 Grass pellets *Gras-kögglar*
1	Pre-mating[a)] *Fyrir fang*	1.040	2.300		1.720	2.900	
	Early pregnancy[b)] *Fyrri hluti meðgöngu*	1.000					
	Late pregnancy[c)] *Seinni hluti meðgöngu*		6.020				
	Total *Alls*	2.040	8.320	0	1.720	2.900	0
2	Pre-mating	0.720			0.450		
	Early pregnancy	0.720					
	Late pregnancy		5.862	2.240			
	Total	1.440	5.862	2.240	0.450	0	0
3	Pre-mating	0.495		7.200	0.770		8.700
	Early pregnancy	5.225		3.670	5.390		1.100
	Late pregnancy	3.160	2.340		2.145		
	Total	8.880	2.340	10.870	8.305	0	9.800
4	Pre-mating	0.700			1.155		
	Early pregnancy	1.400					
	Late pregnancy		3.520				
	Total	2.100	3.520	0	1.155	0	0

a) From beginning of feeding until in the week of mating—*Frá upphafi fóðrunar til fangviku*.
b) Approx. the three first months of pregnancy—*U.þ.b. þrír fyrstu mánuðir meðgöngu*.
c) The latter part of pregnancy and the feeding days after lambing—*Seinni hluti meðgöngu og sauðburður*.

Recordings

The hay and supplements fed and leftovers were weighed every day. Samples were taken from the feed for dry matter (DM) and chemical analysis, and from leftovers for DM analysis. Ewe live weights (LW) were recorded at 2–3 week intervals. Birth weights, number of lambs born and reared per ewe and the sex of lambs were recorded, as well as general information about the health of the animals. The lambs were weighed in early July and again at weaning around 20th September. The average daily temperature inside the shed in System H and outside (for System L) was recorded.

Feed analysis

The DM content was analysed by drying at 105°C for five hours. The ash content was determined by incineration at 550°C for three hours. Crude protein (CP) content was determined by the Kjeldahl method. *In vitro* dry matter digestibility (IVDMD) was measured by the pepsin-cellulase method (Jones and Hayward, 1975).

Statistical methods

Data on DM and energy intake are presented as simple means. Data for ewe LW, lambing rate, lamb birth weights and lamb growth rates,

Table 3. The energy (FFU=Fattening Feed units) and crude protein (CP) content of the rations fed in the high (H) and low (L) input systems in the four years experiment.
3. tafla. Orkuinnihald (F.fe.) og hrápróteininnihald heildarfóðursins í tilrauninni.

Year *Ár*	Period *Tímabil*	FFU/kg DM[a)] *F.fe./kg þe.* H	L	CP/kg DM *Hráprótein, g/kg þe.* H	L
1	Pre-mating[b)]—*Fyrir fang*	0.70	0.71	174	149
	Early pregnancy[c)]—*Fyrri hluti meðgöngu*	0.63	0.64	130	140
	Late pregnancy[d)]—*Seinni hluti meðgöngu*	0.65	0.63	145	151
2	Pre-mating	0.52	0.48	154	137
	Early pregnancy	0.55	0.57	128	127
	Late pregnancy	0.61	0.62	129	120
3	Pre-mating	0.67	0.62	145	128
	Early pregnancy	0.62	0.64	142	157
	Late pregnancy	0.70	0.74	168	204
4	Pre-mating	0.58	0.60	168	173
	Early pregnancy	0.61	0.60	157	148
	Late pregnancy	0.64	0.59	142	132

a) FFU/kg DM = (0.025×%IVDMD–0.561)/1.65.
b) From beginning of feeding until in the week of mating—*Frá upphafi fóðrunar til fangviku*.
c) Approx. the three first months of pregnancy—*U.þ.b. þrír fyrstu mánuðir meðgöngu*.
d) The latter part of pregnancy and the feeding days after lambing—*Seinni hluti meðgöngu og sauðburður*.

was subjected to analysis of variance with covariates, according to the General Linear Models (GLM Anova) of the NCSS software (Hintze, 1987). All diseased and injured lambs and ewes were excluded from statistical analysis. The main model used was:

$$Y_{ij}=\mu+\alpha_i+\beta_x(_{ij})+e_{ij}$$

where Y_{ij} = the record of the j_{th} animal assigned to the i_{th} treatment (system); μ = the overall mean; α_i = the effect associated with the i_{th} treatment (system); $\beta_x(_{ij})$ = covariance effect; e_{ij} = residual effect. For analysis of ewe live weight and number of lambs born per ewe, ewes age was used as covariate in the model. For analysis of lamb growth and birth weights, the ewes age and the lambs sex were used as covariates.

RESULTS

Temperature

The outside temperature was within the range of –15 to +10°C, except in January 1988, when it reached –20°C for a few days. The temperature inside the shed in System H ranged from 0 to 10°C before shearing and 10 to 15°C after shearing.

Feeding

As intended, there were no major differences between the two systems in the quality of the ration fed (Table 3). The feeding strategy resulted in a generally lower quality rations in early pregnancy than pre-mating and in late pregnancy.

As shown in Table 4 the total yearly energy intake from hay and supplements was only 53–71% in System L compared to System H. This difference was due to both fever feeding days and lower intake per day in L.

Live weight

In Years 1 and 3 (Table 5) there were no significant difference between systems in ewe live weight in the week of mating, but in Years 2 (especially) and 4 the H-system ewes were heavier at this time. After three months of preg-

Table 4. Energy intake (FFU[a)] $ewe^{-1}day^{-1}$) and feeding days within periods and for the whole feeding time, and energy intake from supplements and totally per ewe and year in the high (H) and low (L) input systems in the four years experiment.
4. tafla. Fóðurát (F.fe./kind/dag) og fjöldi fóðrunardaga innan tímabila og fyrir veturinn í heild, át á kjarnfóðri og heildarát á kind og ár í kerfunum tveimur (H og L) í tilrauninni.

	Year 1—*Ár 1*		Year 2—*Ár 2*		Year 3—*Ár 3*		Year 4—*Ár 4*	
Period—*Tímabil*	H	L	H	L	H	L	H	L
Pre-mating								
Fyrir fang								
FFU ewe^{-1} day^{-1}—*F.fe./kind/dag*	0.80	0.71	0.57	0.43	0.86	0.70	0.71	0.53
Feeding days—*Fóðrunardagar*	25	26	21	14	25	17	28	35
Early pregnancy								
Fyrri hluti meðgöngu								
FFU ewe^{-1} day^{-1}—*F.fe./kind/dag*	0.72	0.39	0.57	0.48	0.81	0.53	0.72	0.48
Feeding days—*Fóðrunardagar*	91	95	90	91	95	103	94	90
Late pregnancy								
Seinni hluti meðgöngu								
FFU ewe^{-1} day^{-1}—*F.fe./kind/dag*	1.00	0.70	0.99	0.76	1.11	0.54	0.92	0.48
Feeding days—*Fóðrunardagar*	65	48	60	49	61	39	53	34
Whole winter								
Allur veturinn								
FFU ewe^{-1} day^{-1}—*F.fe./kind/dag*	0.82	0.53	0.72	0.56	0.92	0.55	0.78	0.49
Feeding days—*Fóðrunardagar*	181	169	171	154	181	159	175	159
FFU ewe^{-1} $year^{-1}$								
F.fe./kind/ár								
From supplements—*Úr fóðurbæti*	9	4	8	1	18	15	5	1
Total—*Alls*	150	89	123	87	166	87	137	78
L/H×100	59		71		53		57	

a) FFU/kg DM = (0.025×%IVDMD–0.561)/1.65.

Table 5. Average weight of ewes (kg) in the week of mating and after three months of pregnancy in the high (H) and low (L) input systems in the four years experiment.
5. tafla. Meðalþungi áa (kg) í fangviku og eftir þrjá mánuði meðgöngu í H- og L-kerfunum í tilrauninni.

	Week of mating *Fangvika*			After 3 months of pregnancy *Eftir 3 mánuði meðgöngu*		
	H	L	P-value	H	L	P-value
Year 1—*Ár 1*	68.8	68.9	NS	76.3	69.2	<0.001
Year 2—*Ár 2*	68.2	61.8	<0.001	69.1	65.3	<0.01
Year 3—*Ár 3*	66.7	66.2	NS	75.0	67.0	<0.001
Year 4—*Ár 4*	67.2	65.4	<0.05	65.8	64.8	NS

nancy, the L-system always resulted in lower live weight than the H-system, the difference being rather great and highly significant in all years except Year 4.

Lambing performance

Only in Year 2 (Table 6) the difference between the systems in lambing rate approached significance (P=0.07), the L system having lower

Table 6. Lambing performance within years in the high (H) and low (L) input systems in the four years experiment.
6. tafla. Frjósemi áa og fæðingarþungi lamba í kerfunum tveimur (H og L) í tilrauninni.

	Lambing rate[a)] *Fædd lömb eftir á*			Birth weights of twins[b)] *Fæðingarþungi tvílembinga*		
	H	L	P-value	H	L	P-value
Year 1—*Ár 1*	1.89	1.93	0.79	4.04 (48)	3.90 (39)	0.17
Year 2—*Ár 2*	1.82	1.60	0.07	3.81 (50)	3.69 (37)	0.41
Year 3—*Ár 3*	1.78	1.66	0.33	-	-	-
Year 4—*Ár 4*	1.78	1.83	0.68	3.32 (46)	3.58 (46)	<0.01

a) Lambing rate is calculated as number of lambs born per ewe lambing—*Reiknað sem fjöldi lamba á hverja á sem bar.*
b) In Year 3 birth weigths were not fully recorded so that year was not taken into calculations—*Skráning á fæðingarþunga misfórst að hluta Ár 3 svo að það ár er ekki tekið með í útreikningum hér.*

lambing rates. Twin lambs were significantly heavier in System L than System H in Year 4, but in Years 1 and 2 there were no significant differences between systems in this respect.

Lamb growth

In Year 3 birth weigts were not fully recorded so that year could not be taken into calculations for lamb growth. Average growth rates of twin lambs from birth to weaning were 249 and 259 g/day ($P<0.05$) for Systems H (126 lambs) and L (94 lambs), respectively, calculated for all years except Year 3 as one dataset. Comparable values for singles were 300 and 324 g/day ($P<0.05$) for Systems H (13 lambs) and L (23 lambs), respectively. These differences in growth rates between groups were more apparent after the weighing in July than before.

DISCUSSION

Energy intake (Table 4) in the pre-mating period was considerably lower in the L system in all years, lowest in Year 2 (0.43 FFU ewe^{-1} day^{-1}) and Year 4 (0.53 FFU ewe^{-1} day^{-1}). This resulted in 6.4 and 1.8 kg lower live weight in L than H system in the week of mating (Table 5), in Years 2 and 4, respectively, but no significant differences in this respect were found in Years 1 and 3. Differences in lambing rates between systems are significant in none of the experimental years, but the trend in Year 2 with lower lambing rate (Table 6) in System L than System H, can well be explained by the above mentioned differences in feed energy intake and live weight prior to mating. In studies by Bastiman and Williams (1973) and Kneale and Bastiman (1973) ewes without access to shed had lower lambing rates than indoor fed ewes, probably due to environmental stress which was severe enough to reduce the number of viable foetuses, but not of long enough duration to affect ewe condition. It seems very unlikely that the lambing rate of the ewes in system L in the present experiment was affected by such environmental stress, see further discussion below.

It can therefore be concluded that the L system can give similar lambing rates as the H system if a good body condition of ewes at mating is ensured. This is clearly possible in the L system, according to the present findings. The start of the feeding period should not be delayed so much that the ewes loose condition, as was the case in Year 2 when feeding started as late as 28-Dec in System L. It may also be assumed that at least part of the reason for lower feed intake in System L was the result of access to pasture area though it was of very poor quality. It might therefore be advisable to limit the access to pasture in the pre-mating period, in order to ensure that energy intake will be sufficient to obtain high lambing rates.

In the first three months of pregnancy the energy intake in the L system was around 0.5 FFU ewe^{-1} day^{-1} (Table 4) in Years 2–4, but only 0.39 FFU ewe^{-1} day^{-1} in Year 1, but in that year there was little snow and the ewes therefore grazed more than usually. In Year 1, 3 and 4 the ewes in System L had similar live weight's after three months of pregnancy as in the week of mating, but in Year 2 they gained on average 3.5 kg in this period. Judging from these results it seems that 0.5 FFU ewe^{-1} day^{-1}, together with the pasture, may be enough to maintain ewes in the L System. Recommended maintenance allowances for 60–70 kg ewes are in the range 0.60–0.75 FFU ewe^{-1} day^{-1} within the Nordic countries (Ledin, 1984). This indicates that the pasture must have provided approx. 0.1–0.2 FFU ewe^{-1} day^{-1} to the ewes in the L system in the early pregnancy period. However, it also must be kept in mind that the FFU system tends to underestimate the value of roughages, especially those of low quality (Sundstöl, 1993).

In the H system the average feed energy intake in the first three months of pregnancy was in the range 0.7–0.8 FFU ewe^{-1} day^{-1} except in Year 2 when it was only 0.57 FFU ewe^{-1} day^{-1}. The live weight gain from the week of mating until three months of pregnancy, was considerable (7–8 kg) in Years 1 and 3, but in Years 2 and 4 the live weight changes in this period were small. However, the live weight after three months of pregnancy was significantly higher (4–8 kg) in the H system than in the L system, except in Year 4. This does not result in significantly lower birth weights in the L system, which is in good accordance with results from a number of Icelandic sheep feeding trials (Thorsteinsson and Thorgeirsson, 1989).

The average feed energy intake in late pregnancy and after birth was in the range 0.92 to 1.11 FFU ewe^{-1} day^{-1} in the H system, compared to 0.48 to 0.76 FFU ewe^{-1} day^{-1} in the L system. In view of that, and the lower live weight of the L ewes after three months of pregnancy (except in Year 4), it is remarkable that there were no negative effects of the L treatment, compared to the H treatment, on neither lamb birth weights or lamb growth. Actually, twin birth weights were significantly higher for the L treatment in Year 4, when the quality of the feed used was unusually low.

The growth rates of the lambs calculated over all years were slightly higher in the L system, but as these differences were more apparent in the latter part of the summer when the effects of the winter treatment of ewes on lamb growth had decreased, this difference might be more related to the younger age of the lambs in the L system, as growth capacity reduces with advancing age (Þorgeirsson and Thorsteinsson, 1989). It can, however, be concluded that the late winter and spring management in the L system was at least as efficient as in the H system, measured in lamb birth weights and growth.

Because of the younger age of the L than H lambs, they would, roughly estimated, be expected to have on average 1.5–2.0 kg lighter carcasses. The same carcass weights could be obtained in the L as the H system, with an extra autumn grazing period on, for instance, *Brassica* crops. It has been estimated that for each kg in increased carcass weight (including maintenance) 15 FFU would be needed, each FFU costing ca 15 ISK (roughly based on Sveinsson and Ríkharðsson, 1991). The cost of reaching the same carcass weight in the L as in the H system is therefore around 400 ISK/lamb, or 700 ISK ewe^{-1} year^{-1}, assuming 1.75 lambs ewe^{-1} year^{-1}.

The extent of an animals response to cold exposure depends upon the effective ambient temperature (EAT) relative to the lower critical temperature (LCT) of the animal and the duration of exposure (Kennedy *et al.*, 1985). The EAT depends on temperature, wind, humidity, radiation exchange and precipitation (Sasaki and Weekes, 1985). If EAT is below LCT it usually both stimulates feed intake and increases the maintenance requirement due to increased resting metabolic rate (Mossberg, 1992). The lower critical temperature for unshorn ewes, fed near maintenance has been estimated about –15°C (Hahn, 1983). For shorn sheep, similar value is estimated 15 to 20°C (Hahn, 1983; Webster, 1976). In the present experiment the outside temperature rarely went under –15°C. Even though effects of wind, snow and rain in some occasions must have taken EAT under –15, the access to the shed and the fact that the ewes were generally in rather good condition, makes it unlikely that the ewes in the L System were in need to increase their heat production in response to EAT lower than LCT, except maybe in very few cases. It seems, however, more likely that the ewes in the H group needed to produce extra heat to coop with the cold environment, in the first weeks after shearing. In a study by Einarsson (1981) heat production of sheep was doubled after shearing at an ambient temperature of 7–12°C.

The total feed energy intake averaged over the four years was approx. 145 and 85 FFU ewe^{-1} year^{-1} in the H and L systems, respectively. Direct estimates of the increased energy intake due to winter shearing compared to summer shearing under Icelandic conditions have not been done, but from a review of winter and autumn shearing experiments by Þorgeirsson *et al.* (1990) it can be estimated very roughly that 10 FFU ewe^{-1} year^{-1} of the difference in energy intake between the H and L systems was due to the effects of shearing *per se*. Another part of the energy intake difference between the systems is the fewer feeding days in the L system, as a result of delayed lambing time. The feeding days are on average 10% fewer in the L system, and that can almost totally be explained by fewer feeding days around lambing in that system. In light of the higher energy intake per day in that period than in the winter as a whole, a rough estimate of the total energy intake difference between systems caused by the delayed lambing is 15–20% of the energy intake in the H system, or ca 25 FFU ewe^{-1} year^{-1}. The rest of the energy intake difference between the systems, or 25 FFU ewe^{-1} year^{-1} could then be caused by the access of the L ewes to the pasture in the feeding period. No direct costs were related to the winter pasture. The H ewes grazed on cultivated grassland for longer time than the L ewes after lambing, because of the difference in lambing time between the systems. On the other hand, the L ewes grazed on cultivated land for some time before lambing, so the net difference between systems in the cost of grazing cultivated pasture in the spring can be assumed zero.

The annual costs of housing per sheep have been estimated, taking into account the cost of investment, government grants, annual depreciation and the cost of maintenance (Gunnar Jónasson, personal communication). In January 1998 the annual cost per sheep is estimated around 1025, 1390 and 1570 ISK for, respectively, shed without slatted floors, shed with slatted floors and shallow (1–1.5 m) dung pit, and shed with slatted floor and deep (2.5 m) dung pit. For uninsulated houses the costs would be approx. 50 ISK lower per sheep and year.

Recent estimates of a value of a typical wool yield are around 360 ISK ewe^{-1} year^{-1} for the winter shearing practice (Eyþórsdóttir, 1997). The costs of the extra work of gathering the flock together and various inconvenience related to summer shearing, together with very low quality of that wool, means that the net outcome of taking wool by that practice can be considered zero. In studies by Einarsson (1980) 48% lower prices were obtained for wool from non-slatted than slatted house when ewes were kept indoors under poor ventilation, but with better ventilation the differences were only 12%. It has been shown that the wool quality in non-slatted sheds is much better if the sheep are free to go outside, though not as good as in well ventilated sheds with expanded steel mesh floors (Einarsson, 1982; Eyþórsdóttir, 1989).

If lambing commences indoors, it is a great advantage to have slatted floors, with respect to working conditions and hygienic aspects. Indoor lambing is considerably more labour intensive than outdoor lambing. From research made by Einarsson (1978) it can be seen that delaying lambing can save at least 0.5 hour ewe^{-1} year^{-1} work. Outdoor lambing is therefore an alternative that can be used to "by-pass" the need of slatted floors and to reduce labour, if weather conditions allow that, which becomes more likely as lambing is delayed. Summer-shearing seems more logical under that conditions than when houses with slatted floors are used.

According to report from the Icelandic Agricultural Economics Institute (1995), variable costs in homemade roughage is on average 8–9 ISK/FFU. Taking into account that the supplement proportion was higher in the H system, the extra feed used in that system over the L system will be evaluated on 10 ISK/FFU. If, as suggested above, delaying lambing *per se* saves 25 FFU or 250 ISK ewe^{-1} year^{-1} and 0.5 hour work (×1000 ISK/hour= 500 ISK ewe^{-1} year^{-1}), these savings do slightly more than cancelling out the 700 ISK ewe^{-1} year^{-1} that were suggested to be the cost of the extra autumn grazing needed to obtain the same carcass weights in the L as the H system.

To get the 360 ISK ewe^{-1} year^{-1} from winter shearing, instead of no net income from summer shearing, shed insulation costing 50 ISK ewe^{-1} year^{-1}, slatted floors and at least shallow dung cellar, costing 365 ISK ewe^{-1} year^{-1} more than houses without slats, would be needed and also an extra feed of 10 FFU or 100 ISK ewe^{-1} year^{-1}. The net outcome of winter shearing *per se* is therefore –155 ISK ewe^{-1} year^{-1}.

If, in addition, the access to pasture in the winter is assumed to have saved 25 FFU or 250 ewe^{-1} year^{-1} in the L system, that system gives on the whole 400–500 ISK ewe^{-1} year^{-1} better net outcome than the H system. The figures in this economical evaluation should not be taken to seriously, as there are many factors related to the situations on each farm that can influence them. However, this evaluation indicates quite strongly that the L system under certain circumstances have advantages over the H system. It must though be kept in mind that other combinations of management practices than those in the H and L system here are possible.

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