58th Annual Meeting of the
European Association for Animal Production
Dublin, Ireland, 26-29 August 2007

The development of artificial insemination in sheep and goats in Iceland

Ólafur R. Dýrmundsson
The Farmers Association of Iceland
Bændahöllin, 107 Reykjavík, Iceland
Tel: +354-563-0300/0317 Fax: +354-562-3058
E-mail: ord@bondi.is Webpage: www.bondi.is

Jón Viðar Jónmundsson
The Farmers Association of Iceland
Bændahöllin, 107 Reykjavík, Iceland
Tel: +354-563-0300/0314 Fax: +354-562-3058
E-mail: jvj@bondi.is Webpage: www.bondi.is

Thorsteinn Ólafsson
Southram Artificial Insemination Centre
Austurvegur 1, 800 Selfoss
Tel: +354-480-1810 Fax: +354-480-1818
E-mail: steini@bssl.is Webpage: www.bssl.is

Introduction

Icelandic sheep farming is characterised by the breeding of native, North-European short-tailed sheep grazed on extensive rangeland pastures in summer and fed indoors with silage or hay in winter. While sheep production is of great economic and social importance in most rural districts, goat keeping, also of a native breed, is more a hobby than a commercial activity. Lamb is the main product of the sheep industry (90%) while wool, skins and milk are regarded as by-products (Dýrmundsson, 2006 a & b; Dýrmundsson and Pálmadóttir, 2004; Dýrmundsson, Thorvaldsdóttir and Kópsdóttir, 2006). Due to their northerly location both Icelandic sheep and goats breed seasonally, i.e. are mainly mated in December for lambing in May. (Dýrmundsson and Ólafsson, 1989). Both these Nordic breeds are characterized by great genetic diversity (horned/polled, white/coloured), they are of small size compared to other sheep and goat breeds with ewes weighing 60-70 kg, rams 90-100 kg, does 35-60 kg and bucks 60-80 kg, prolific, especially the sheep with 1.7-2.0 lamb born per ewe, and both breeds are hardy and well adapted to the harsh climate of Iceland (Dýrmundsson, 2002; Dýrmundsson, 2005 a; Dýrmundsson, 2005 b; Dýrmundsson and Pálmadóttir, 2004; Icelandic Livestock Breeds, 2004; Sveinsdóttir and Dýrmundsson, 1994).

Sheep AI since 1939

Artificial insemination in sheep has been practiced in Iceland since 1939 and is now probably more widely applied there than in any other European country, except France (Compte rendu annuel sur l´insémination artificielle ovine, 2006; Dýrmundsson and Ólafsson, 1989; Ólafsson, 2004 a). In the very first years of sheep AI, namely from 1939-1943, the sole purpose was the breeding of strains of sheep resistant to the lung disease “Jaagziekte” imported with Karakul sheep in 1933 and, together with “Maedi, were causing disastrous losses at the time (Gíslason, 1945). It is of historical interest to note that this was probably the first effort in the world to apply genetic selection for disease resistance (Pálsson, 1943). Since then the primary aim of AI in sheep in Iceland has been the distribution of genetic material, i.e. breed improvement, mainly for lamb production (meat) with emphasis on carcass quality and ewe productivity. Conservation of exotic traits (colours, leadersheep trait, fourhornedness) has also benefitted from AI (Dýrmundsson, 2002; Dýrmundsson, 2005 a; Jónmundsson, 2003). Already by 1960 sheep AI had gained momentum in some districts, not least due to strict limitations on the transport and distribution of live sheep between flocks and communities because of disease control (Dýrmundsson, 2006 c; Jónmundsson, 1986; Jónmundsson, 2003; Thorgeirsson, 2007). In fact in some districts no transfer of live sheep is allowed between flocks. By the 1970s some 3% of ewes were inseminated (Dýrmundsson, 1977 a) and since then AI has become one of the three pillars of breeding work together with individual recording and assessment of live sheep by ultrasonic scanning (Jónmundsson, 2003). Technical progress, such as the use of frozen semen has generated further advancement in recent years (Ólafsson, 2004).

Ram selection and management

The selection of rams for the sheep AI services is based on the nationwide, individual recording scheme of the Sheep Breeding Societies supervised by the Farmers Association of Iceland, now including some 90% of the national sheep flock (Jónmundsson, 2006). All the rams are bought from commercial flocks, mainly in the range of 200-500 winterfed sheep, up to 1000. They are of outstanding breeding merit, normally progeny tested, and scrapie genotyping, based on DNA tests, are amongst the selection criteria. Thus VRQ/VRQ rams are excluded (Sigurdarson, 2004). The primary criteria are prolificacy, lamb carcass weight and meat quality characteristics in relation to the EUROP classification scheme (Dýrmundsson, 2006 b; Jónmundsson, 2003. The rams are transferred from their flocks to each of the two AI centers according to strict sanitary standards. Many of the AI rams are moved between centers, between years, and some of them are used for a few years in the AI services. AI rams cannot be moved or returned to farms. They are fed and managed similarly to other sheep, housed in group pens from November to May and grazed on enclosed pasture, isolated from other sheep, from June to October. Ram catalogues, with colour photographs and fairly detailed information about each of the 40-50 rams in the AI services per year, are distributed to flock owners in late November. Internet access is also available under “hrútaskrá” on www.bssl.is

The present use of the sheep AI services

Sheep AI is now applied in 80-90% of the 2436 commercial and 428 hobby sheep flocks in Iceland. Furthermore, frozen ram semen has been exported to the USA since 1998 (Ólafsson, 2006 b) and since 2006 to Canada. **Table 1** shows the number of ewes, including ewe lambs, inseminated annually since 1984. The upward trend has been particularly clear during the last decade (Jónmundsson, 2003 & 2006; Ólafsson, 2004 b), reaching 30.885 ewes in 2006 accounting for 8.5% of the national ewe flock, both historically the highest number and percentage of AI ewes. Although the majority of the ewes are inseminated with fresh semen there has been a growing interest in recent years in using frozen semen, now for 2.200 ewes out of the total of 30.885 in 2006.

Table 1 **Number of inseminated ewes in Iceland 1984-2006**

Year	***AI ewes***		***Year***	***AI ewes***
2006	30885		1994	16537
2005	30450		1993	13478
2004	29987		1992	11862
2003	26589		1991	11826
2002	28578		1990	15160
2001	25261		1989	11053
2000	22540		1988	18859
1999	18899		1987	14498
1998	19977		1986	19222
1997	16396		1985	24445
1996	17868		1985	23978
1995	12407			

Semen collection and processing

Most of the semen collection takes place in December, normally from rams ranging in age from 18 months to five years. Ram lambs are seldom kept at the AI centres but old rams, i.e. six to eight years, are occasionally used. Although little is know about the seasonal variation in semen quantity and quality both late October and November collections have been successful in most cases (Ólafsson, 2007). Considerable seasonal variation in testis size has been recorded with the highest values in autumn (Dýrmundsson, Sigtryggsson and Thorsteinsson, 1981). Icelandic rams clearly display maximum libido in mid-winter but it appears that they may be sexually active at other times of the year (Dýrmundsson, 1981; Dýrmundsson and Adalsteinsson, 1980). The semen is collected by artificial vagina, with the aid of an oestrous ewe, early in the morning **(Figures 1-3).** The artificial vagina is washed with hot water, sterilized with spiritus fortis and allowed to dry before use. It is filled with 52^{o}C warm water with an inside temperature of 40-42^{o}C (Ólafsson, 2007). The processing of the semen also follows a standard procedure at both AI centres. In fact the AI techniques introduced by the pioneer (Gudmundur Gíslason, 1939), and further developed by him, are still applied, however, with modifications (Dýrmundsson and Ólafsson, 1989; Ólafsson, 2004 b; Ólafsson, 2007). The processing of the semen includes, without going into any details, dilution with a skim milk extender at the rate of 1:2 to 1:3 and density of $1x10^{9}$ cells/ml, transfer to medium IMV straws containing five inseminate doses of 0.1 ml each and then gradual cooling down to 5^{o}C over the next six hours. However, the processing of frozen semen developed since 1979 deviates considerably from that of fresh semen (Ólafsson, 1980 a & b; Dýrmundsson and Ólafsson, 1989). In that case the dilution rate is at least 1:4, the inseminate dose contains 200 million spermatozoa and the semen is transferred to mini IMV straws (Ólafsson, 2007). Fresh semen is considered acceptable for use when the motility of the spermatozoa is more than 55-60% but the minimum requirement for frozen semen is 50% (Ólafsson, 2007). It is of interest to note that the Icelandic skim milk extender used for several decades has proven to be much superior to both the German Minitüb and the French IMV ram semen extenders. This particularly applies to the conception rate in spite of the fact that the livability of the spermatozoa in the laboratory proved to be superior when the imported extenders were tested (Ólafsson, 2004 b & c).

Figures 1-3 **Semen collection at Southram Artificial Insemination Centre**

Transport and farm application

There are no railways in Iceland so all semen containers are sent by road and/or air transport. Flock owners in all parts of the country can order ram semen according to the AI ram catalogue referred to above. Both commercial and hobby flocks can equally use the AI services. The minimum number of doses delivered to a flock is three and the cost of AI per ewe may vary from 6-8 Euros or 8-11 US Dollars. As a general rule the semen containers are transported to the various districts in late morning and early afternoon, up to 800 km, often both by road and air. Most of the inseminators are local farmers who have attended a minimum of 1-day technical training courses under veterinary supervision.

Synchronization of oestrus and timing of AI

After the introduction of oestrus synchronization in Iceland in the 1970s its application helped to advance the use of sheep AI by enabling farmers to select the best ewes for fixed-time AI and to plan the work more efficiently (Dýrmundsson, 1977 a & b). Oestrus synchronization, still used in several flocks, has, however, now become much less important with the exception of small flocks. As in the first trials over 30 years ago the standard practice of oestrus synchronization is to treat the ewes with Veramix® (Upjohn) intravaginal progestagen sponges, without the use of PMSG, for 14 days and inseminate them 55 (50-60) hours after removal from the vagina. This fits well to the mean duration of oestrus of two days in adult ewes (Dýrmundsson, 1978; Loftsson and Dýrmundsson, 1990). No significant differences have been revealed in the duration of synchronized and natural oestrus (Loftsson and Dýrmundsson, 1990). If oestrus is not synchronized ewes coming into heat are detected with a teaser ram in the morning for AI in the afternoon. Whether the ewes have a synchronized oestrus or not they are assembled and kept in a pen close to rams until AI takes place (Ólafsson, 2006 a). In some cases ewes may be inseminated at the second oestrus after sponge removal, i.e. 18-19 days later after heat detection with a teaser ram (Dýrmundsson and Ólafsson, 1989, Ólafsson, 2006 a).

Insemination process in the sheep house

When the ewes are inseminated the temperature in the sheep house should be above freezing point and sufficient light must be ensured. Normally the inseminator is assisted by the person who is responsible for the daily feeding and management of the flock. In many cases the farmer has attended an AI course and inseminates himself, often with the help of a member of his family, familiar with the flock. Often the ewes to be inseminated represent 10-15% of the ewe population , and irrespective of whether AI takes place on one or more days during the mating season, all the ewes should be inseminated in the pen where they have been assembled. This should be done with a minimum of disturbance. In fact the ewes should be treated gently, without any rough handling, and other stressful conditions should be avoided (Dýrmundsson and Loftsson, 1989 b; Ólafsson, 2006 a). The use of the duckbill speculum was abandoned several years ago and this has reduced discomfort and stress to the ewe which is held in a normal standing position during the AI operation. The insemination pipette is inserted into the anterior part of the vagina, close to the cervix, where the semen is deposited. (Dýrmundsson and Ólafsson, 1989).

Fertility results

The AI work is planned in such a way that ewes are inseminated early in the mating season so that those not conceiving return to service and can be mated naturally in late December or early January after an oestrous cycle of 16-17 days (Dýrmundsson, 1978). Due to a considerable individual variation in semen quality conception by individual rams may vary from 60-80%. While avarage conception rates in ewes of 70% for fresh semen and 50% for frozen semen are generally achieved there is considerable variation in fertility results, i.e. conception rates of 60-80% for fresh semen (Ólafsson, 2004 b) and 35-65% for frozen semen (Ólafsson, 2006 b) are generally recorded. Several environmental /management factors can effect AI fertility results such as the inseminator, the temperature in the sheep house as well as transport time and distance. Thus compared with ewes mated naturally, with over 90% conception rate at first mating, there is still scope for improvement in conception to AI. Every year sporadic cases of very high conception rates are recorded in AI ewes in individual flocks, even up to 100%. Since ewes are normally inseminated earlier in the mating season than naturally bred ewes when their ovulation rate is presumably not yet at a maximum, their prolificacy (lambing rate) tends to be lower and there is no evidence that AI *per se* is associated with reduced prolificacy. Here, again, there is considerable flock variation but lambing rates of 1.7-1.8 per ewe are generally achieved in AI ewes. **Tables 2, 3 & 5** summarize AI fertility results from East-Iceland in recent years, an area with the longest transport distances and with a combination of road-air-road haulage, often delayed by bad weather conditions such as fog or snowstorms causing unexpected delays, even to the extent that recommended timing in the afternoon or evening (day 1) cannot be kept and the semen is not used until the following day (day 2). Thus the conception rates are generally lower there than in other parts of the country, such as in South-Iceland (**Tables 4 & 6**), but lambing rates are similar. Some yearly variation in fertility results is evident in these regions as elsewhere. The relatively low conception rates of ewes inseminated on day 2 (**Table 2 & 4**) clearly reflect disrupted timing of AI and this may also, at least partly, account for the poor conception rates of ewes synchronized for fixed-time AI. Although early trials did not reveal any negative effects on ewe fertility of progestagen sponge treatment in conjunction with fixed-time AI (Dýrmundsson, 1977 a & b), later survey data and subsequent experience have shown that this synchronization treatment tends to lower conception rate while not affecting prolificacy (Thórarinsson, 1985; Dýrmundsson and Ólafsson 1989; Vilmundarson, 1989; Ólafsson, 2006 a) One of the means of improving conception rates is double insemination, i.e. both on day 1 and 2, so far not considered justifiable from an economic point of view (Dýrmundsson and Loftsson, 1989 a). However, this may become feasible with a more widespread use of frozen semen. Although the early trials using frozen semen were not considered to give satisfactory results (Ólafsson, 1980 a & b; Ólafsson, Guðbjörnsson, Sigbjörnson and Hallgrímsson, 1983) there has been a revival of interest in recent years in using frozen semen for AI as better fertility results are being obtained. As indicated above and in **Table 6** they are normally better than those presented in **Table 5**. The development, dating back to 1979, is indeed promising (Ólafsson, 2004) and the use of frozen semen could further advance the use of AI in the country, particularly in remote districts as pointed out by Ólafsson (1980 b).

Table 2 **Conception rates of ewes inseminated with fresh semen in East-Iceland in 2001-2007**

Year	***Natural oestrus AI on day 1***		***Natural oestrus AI on day 2***		***Synchronized oestrus AI on day 1***	
	n	%	n	%	n	%
2007	2636	61.5	187	39.0	298	41.9
2006	2519	65.4	298	43.0	70	45.7
2005	2628	58.2	458	31.4	126	22.2
2004	3123	63.8	242	50.0	75	36.0
2003	2173	61.9	127	44.1	158	35.4
2002	3096	61.2	384	36.2	241	39.4
2001	3250	65.7	45	37.8	428	43.7
Source: Thórarinn Lárusson and Gudfinna Harpa Árnadóttir, unpublished results from the Agricultural Association of East-Iceland, 2007						

Table 3 **Prolificacy (lambing rates) of ewes inseminated with fresh semen in East-Iceland in 2001-2007**

Year	***Natural oestrus AI on day 1***		***Natural oestrus AI on day 2***		***Synchronized oestrus AI on day 1***	
	n	lambs/ewe	n	lambs/ewe	n	lambs/ewe
2007	2636	1.75	187	1.63	298	1.72
2006	2519	1.79	298	1.66	70	1.88
2005	2628	1.73	458	1.60	126	1.93
2004	3123	1.79	242	1.72	75	1.93
2003	2173	1.80	127	1.63	158	1.71
2002	3096	1.78	384	1.60	241	1.63
2001	3250	1.77	45	1.53	428	1.66
Source: Thórarinn Lárusson and Gudfinna Harpa Árnadóttir, unpublished results from the Agricultural Association of East-Iceland, 2007						

Table 4 **Conception rates of ewes inseminated with fresh semen in South-Iceland in 1997-2005**

Year	***Natural oestrus AI on day 1***			***Natural oestrus AI on day 2***			***Synchronized oestrus AI on day 1***		
	n	%	lambs/ewe	n	%	lambs/ewe	n	%	lambs/ewe
2005	1330	71.8	1.84	99	62.6	1.65	51	78.4	1.80
2004	1278	77.3	1.86	32	59.4	1.84	19	42.1	1.63
2003	1545	78.7	1.85	59	67.8	1.80	104	64.4	1.81
2002	199	75.4	1.89	24	58.0	1.86	43	51.0	1.82
2001	1669	73.6	1.85				105	65.7	1.67
2000	702	73.8	1.85	19	47.4	1.33	226	54.0	1.79
1999	1072	73.4	1.81	10	50.0	1.60	39	64.1	1.72
1998	1397	72.7	1.84	4	75.0	2.00	220	55.9	1.81
1997	1293	65.2	1.79	5	60.0	2.00	194	49.5	1.66
Source: Thorsteinn Ólafsson, unpublished results from Southram Artificial Insemination Centre, South-Iceland, 2007									

Table 5 **Fertility results of ewes inseminated with frozen semen at natural oestrus in East-Iceland in 2005-2007**

Year	*n*	*Conception rates %*	*Prolificacy lambs/ewe*
2007	322	36.0	1.71
2006	353	44.5	1.68
2005	456	45.0	1.63
Source: Thórarinn Lárusson and Gudfinna Harpa Árnadóttir, unpublished results from the Agricultural Association of East-Iceland, 2007			

Table 6 **Fertility results of ewes inseminated with frozen semen at natural oestrus in South-Iceland in 2004 and 2005**

Year	*n*	*Conception rates %*	*Prolificacy lambs/ewe*
2005	961	46.5	1.69
2004	1681	49.1	1.69
Source: Thorsteinn Ólafsson, unpublished results from Southram Artificial Insemination Centre, South-Iceland, 2007			

Impact of AI on breeding work

As indicated above the main aim of sheep AI in the country has been the dissemination of genetic material, mainly for meat production. The contribution of AI to the breed improvement is indeed substantial and unquestionable. Örnólfsson, Jónmundsson, Thorgeirsson and Eythórsdóttir (2007). According to Árnason and Jónmundsson (2007 a & b) AI creates good genetic links between flocks and facilitates the use of BLUP in breeding value estimation. Although rams cannot be selected for the AI services from all districts in Iceland, due to transfer restrictions aimed at controlling the spread of contagious sheep diseases, (Jónmundsson, 2003; Dýrmundsson, 2006 b), both AI centres can always provide semen from both horned and polled rams of outstanding genetic merit. Most farmers are confident that carefully selected AI rams, taking into account possible inbreeding obstacles, will have positive impacts on the genetic make-up of their flocks. (Jónmundsson, Kristjánsson and Skúlason, 2007). This confidence is, for example, reflected in the fact that some 60% of replacement ram lambs and 15% of replacement ewe lambs in the country are sired by AI rams. Beneficial effects of AI on the conservation of exotic traits in the breed, although of little or no economic significance, are also well recognized throughout the country. Furthermore, scrapie genotyping of AI rams is presumably having a positive impact on selection against scrapie-susceptible genotypes and thus it benefits the national scrapie eradication plan (Dýrmundsson, 2006 c).

Goat AI trials

The Iceland Goat Breed is an isolated, endangered population of Nordic origin numbering only 449 winterfed animals in 45 flocks found in most parts of the country (Sveinsdóttir and Dýrmundsson, 1994; Dýrmundsson, 2005 b). As with sheep there are strict limitations on the movement and distribution of live goats between flocks due to disease control measures (Dýrmundsson, 2006 c). Thus goat owners have been interested in making use of AI. However, due to the small numbers involved, little economic importance and the cost of operating AI services, only small farm trials have been carried out so far, both under the veterinary supervision of Thorsteinn Ólafsson. He collected semen from one buck in a goat flock in South-Iceland and inseminated a few goats on three farms in 1998, one in South-Iceland and two in West-Iceland. Then in 2006 he collected semen from five bucks on one of the farms in West-Iceland where AI took place in 1998 and inseminated 11 goats on one farm in North-Iceland. Fresh semen was used, sheep AI techniques were applied in both years and oestrus was synchronized with Veramix® (Upjohn) sponges, the trials taking place in the end of November and the beginning of December (Dýrmundsson, 1999 & 2007; Ólafsson 2004 a). Although the results of these first goat AI trials in Iceland were poor with only a few does conceiving (20-30%) it is, however, clear that the trials have already contributed to the conservation of exotic traits, such as polledness and the badgerface colour. Goat AI trials may continue, such work is still in its infancy in Iceland but both advantages and disadvantages must be considered. Thus care must be taken not exacerbate the high level of inbreeding (Adalsteinsson, Dýrmundsson, Bjarnadóttir and Eythórsdóttir, 1994) by using a few AI bucks too extensively in this small goat population.

Conclusions

Sheep AI services in Iceland are well established and enjoy a high level of confidence in the sheep farming community. They are indeed of utmost importance in the nationwide breeding work and have had a great impact on breed improvement, especially during the last 40 years. Although sheep AI has been mainly based on the use of fresh semen there has been a positive development and enhanced interest in recent years in using frozen semen. However, the speed of such changes will depend on factors such as fertility results and cost efficiency. On the whole the use of AI may well continue to increase in the Icelandic sheep industry in the foreseeable future. Goat AI, still in its early stage of development and while not being of comparable economic significance, is likely to continue to contribute mainly to conservation efforts within the endangered goat breed.

References

Adalsteinsson, S., Dýrmundsson, Ó.R., Bjarnadóttir, S. and Eythórsdóttir E. (1994). Skyldleikarækt í íslenskum geitum. *Icelandic Agricultural Sciences 8, 99-105*. (In Icelandic with a summary in English).

Árnason, Th. and Jónmundsson, J.V. (2007 a). Multiple trait genetic evaluation of ewe traits in Icelandic sheep. *Proceedings of the 58th Annual Meeting of the European Association for Animal Production, Dublin, Ireland, 26-29 August 2007. Book of Abstracts, No. 13, page 244.Wageningen Academic Publishers.*(ISBN 978-90-8686-045-6, ISSN 1382-6077).

Árnason, Th. and Jónmundsson, J.V. (2007 b). Kynbótamat afurðaeiginleika íslenskra áa. *Fjölrit LBHÍ nr. 14. Íslensk búfjárrækt. Málstofa til heiðurs Hjalta Gestssyni níræðum, Hótel Sögu, Reykjavík, 17. nóvember 2006*, 55-62. Ritstjóri: Ólafur R. Dýrmundsson. Landbúnaðarháskóli Íslands, 108 bls. (ISSN 1670-5785, in Icelandic).

Compte rendu annuel sur l'insémination artificielle ovine. Campagne 2005. La campagne d´IA ovine 2005. Eds: G. Perret, G. Lagriffoul and A. Castres. *Compte rendu 01 06 79131. September 2006*, Institut de l´Élevage, Paris, France. 31 pp.

Dýrmundsson, Ó.R. (1977 a). Practical aspects of artificial insemination and oestrus synchronization in Iceland sheep. *Proceedings of the 28th Annual Meeting of the European Association for Animal Production, Brussels, Belgium, 22-28 August 1977*. Mimeograph 6 pp.

Dýrmundsson, Ó.R. (1977 b). Synchronization of oestrus in Iceland ewes with special reference to fixed-time artificial insemination. *Acta Agriculturae Scandinavica 22*, 250-252.

Dýrmundsson, Ó.R. (1978). Studies on the breeding season of Icelandic ewes and ewe lambs. *Journal of Agricultural Science, Cambridge 90*, 275-281.

Dýrmundsson, Ó.R. (1981). Out-of-season breeding in Icelandic sheep. *Journal of Agricultural Research in Iceland 13*, 49-54.

Dýrmundsson, Ó.R. (1999). Geitfjárrækt. *Til Búnaðarþings 1999*, 75-80. (Annual Report for 1998 in Icelandic).

Dýrmundsson, Ó.R. (2002). Leadersheep: the unique strain of Iceland sheep. *Animal Genetic Resources Information (AGRI) 32*, 45-48.

Dýrmundsson, Ó.R. (2005 a). Four-hornedness; a rare peculiarity still found in Icelandic Sheep. *The Icelandic Sheep Breeders of North America Newsletter 9 (4), 6-8,* and *IceNewes & Ramblings, Issue 1, 2006, 17-21.* (British Icelandic Sheep Breeders Newsletter).

Dýrmundsson, Ó.R. (2005 b). The Iceland goat: past and present. *Animal Genetic Resources Information (AGRI) 36*, 53-59.

Dýrmundsson, Ó.R. (2006 a). Sustainability of sheep and goat production in North European countries – From the Arctic to the Alps. *Small Ruminant Research 62*, 151-157.

Dýrmundsson, Ó.R. (2006 b). Sheep and goat farming in Iceland – summary of the situation in 2006. *Proceedings of the 29th InterNorden Meeting, Lihasula Farm, Finland, 29 June-2 July 2006*, 42-43.

Dýrmundsson, Ó.R. (2006 c). National sheep identification and control of contagious diseases of sheep in Iceland. *Proceedings of the 29th InterNorden Meeting, Lihasula Farm, Finland, 29 June-2 July 2006*, 21-21.

Dýrmundsson, Ó.R. (2007). Geitfjárrækt. *Til Búnaðarþings 2007*, 89-94. (Annual Report for 2006 in Icelandic).

Dýrmundsson, Ó.R. and Adalsteinsson (1980). Coat-color gene suppresses sexual activity in Icelandic sheep. *The Journal of Heredity 71*, 363-364.

Dýrmundsson, Ó.R. and Loftsson, E. (1989 a). Timing of artificial insemination in sheep and goats. *Proceedings of the 40th Annual Meeting of the European Association for Animal Production, Dublin, Ireland, 27-31 August 1989*. Mimeograph 11 pp.

Dýrmundsson, Ó.R. and Loftsson, E. (1989 b). Tímasetning sæðinga áa með samstillt gangmál. *Freyr 85 (22),* 926-927 & 930. (In Icelandic).

Dýrmundsson, Ó.R. and Ólafsson, Th. (1989). Sexual development reproductive performance, artificial insemination and controlled breeding, 95-104. In: *Reproduction, Growth and Nutrition in Sheep. Dr. Halldór Pálsson Memorial Publication*. Eds: Ólafur R. Dýrmundsson and Sigurgeir Thorgeirsson. Agricultural Research Institute and Agricultural Society, Iceland, 213 pp.

Dýrmundsson, Ó.R., Pálmadóttir, J.E. (2004). Icelandic sheep – a breed of great genetic diversity – providing high quality products of meat, wool, skins and milk. *Terra Madre, World Meeting of Food Communities, Slow Food, Turin, Italy, 20-23 October 2004.* Mimeograph 1 p.

Dýrmundsson, Ó.R. Sigtryggsson, P. and Thorsteinsson, S.Sch. (1981). Seasonal variation in testis size of Icelandic rams. *Journal of Agricultural Research in Iceland* 13, 55-60.

Dýrmundsson, Ó.R., Thorvaldsdóttir, J.B, Kópsdóttir, Th.S. (2006). Local, small scale production and processing of milk from the native Iceland goat and sheep breeds. *Terra Madre, World Meeting of Food Communities, Slow Food, Turin, Italy, 26-30 October 2006*, Mimeograph 4 pp. In: *The Icelandic Sheep Breeders of North America Newsletter 11 (1)*, 14-16, and *IceNewes & Ramblings, Issue 1/2007*, 9-12 (British Icelandic Sheep Breeders Newsletter).

Gíslason, G. (1945). Sæðing húsdýra. *Búnaðarrit 58*, 84-119. (In Icelandic).

Icelandic Livestock Breeds – Islandske Husdyrraser – Íslensk búfjárkyn – (2004). Brochure 20 pp. published by the Farmers Association of Iceland in cooperation with the Agricultural Genetic Resources Committee and the Nordic Gene Bank for Domestic Animals. Ed.: Ó.R. Dýrmundsson (ISBN 9979-885-02).

Jónmundson, J.V. (1986). Sheep breeding organisation and recording in Iceland. *Proceedings of the New Zealand Society of Animal Production 46*, 111-145.

Jónmundsson, J.V. (2003). Recent developments in sheep breeding in Iceland. *Proceedings of NJF-Seminar 338 & InterNorden 2002, 27-30 June 2002*, 93-94. Ed.: Ó.R. Dýrmundsson. The Farmers Association of Iceland, Reykjavík, Iceland. 139 pp. (ISBN 9979-885-01-7).

Jónmundsson, J.V. (2006). Yfirlit um skýrsluhald fjárræktarfélaganna árið 2005. *Freyr 102 (4)*, 22-27. (In Icelandic).

Jónmundsson, J.V., Kristjánsson, Th. and Skúlason, R. (2007). Er Hestféð Þistilfjarðarfé eða Þistilfjarðarféð Hestfé? *Fjölrit LBHÍ nr. 14. Íslensk búfjárrækt. Málstofa til heiðurs Hjalta Gestssyni níræðum, Hótel Sögu, Reykjavík, 17. nóvember 2006*, 83-93. Ritstjóri: Ólafur R. Dýrmundsson. Landbúnaðarháskóli Íslands, 108 bls. (ISSN 1670-5785, in Icelandic).

Loftsson, E. and Dýrmundsson, Ó.R. (1990). Duration of oestrus in Icelandic ewes and ewe lambs. *Icelandic Agricultural Sciences 4*, 71-76.

Ólafsson, Th. (1980 a). Insemination of sheep with frozen semen. *Zuchthygiene 15*, 50-59.

Ólafsson, Th. (1980 b). Djúpfrysting hrútasæðis. *Ráðunautafundur 1980*, 150-154. (In Icelandic).

Ólafsson, Th. (2004 a). Sæðingar á refum, svínum, geitum og alifuglum. *Dýralæknatal, búfjársjúkdómar og saga*, 354-355. Dýralæknafélag Íslands, Reykjavík, 423 pp. (ISBN 9979-60-954-0, in Icelandic,).

Ólafsson, Th. (2004 b). Sauðfjársæðingar á Íslandi. *Dýralæknatal, búfjársjúkdómar og saga*, 382-390. Dýralæknafélag Íslands, Reykjavík, 423 pp. (ISBN 9979-60-954-0, in Icelandic,).

Ólafsson, Th (2004 c). Starfsskýrsla 2003. *Árrit Búnaðarsambands Suðurlands 2003, 34 (1), 2004*, 52-55. (ISSN 1605 7538, Annual Report for 2003, in Icelandic).

Ólafsson, Th. (2006 a). Sauðfjársæðingar. *Hrútaskrá 2006-2007*, 7. Sauðfjársæðingastöð Suðurlands og Sauðfjársæðingastöð Vesturlands (ISSN 1608-084X, in Icelandic) and on: www.bssl.is .

Ólafsson, Th. (2006 b). Fryst hrútasæði. *Árrit Búnaðarsambands Suðurlands 2006, 36 (1), 2006, 35-39*. (ISSN 1605 7538, Annual Report for 2005, in Icelandic).

Ólafsson, Th. (2007). Sæðistaka. Úr gæðahandbók fyrir sauðfjársæðingastöðvarnar (In Icelandic).

Ólafsson, Th., Gudbjörnsson, S., Sigbjörnsson, P. and Hallgrímsson, S. (1983), *Sauðfjárræktin*, 164-165. Ritstjóri: Sveinn Hallgrímsson. Búnaðarfélag Íslands, 175 bls. (In Icelandic).

Pálsson, H. (1943). Rannsókn á viðnámsþrótti íslensks sauðfjár gegn mæðiveikinnni. *Atvinnudeild Háskólans. Rit Landbúnaðardeildar, A-Flokkur, Nr. 1, 28 pp*. (In Icelandic).

Sigurðarson, S. (2004). Baráttan við riðuveiki á Íslandi. *Dýralæknatal, búfjársjúkdómar og saga*, 356-375. Dýralæknafélag Íslands, Reykjavík, 423 pp. (ISSN 9979-60-954-0, in Icelandic).

Sveinsdóttir, H.E. and Dýrmundsson, Ó.R. (1994). The Iceland goat breed. *Icelandic Agricultural Sciences 8*, 93-97.

Thorgeirsson, S. (2007). Hjalti Gestsson og búfjárræktin. Fjölrit LBHÍ nr. 14. *Íslensk búfjárrækt. Málstofa til heiðurs Hjalta Gestssyni níræðum Hótel Sögu, Reykjavík, 17. nóvember 2006*, 15-20. Ritstjóri: Ólafur R. Dýrmundsson. Landbúnaðarháskóli Íslands, 108 bls. (ISSN 16-10-5783, in Icelandic).

Thórarinsson, G. (1985). Sæðingar sauðfjár á Íslandi. Aðalritgerð við Búvísindadeild Bændaskólans á Hvanneyri, 41 bls. (In Icelandic).

Vilmundarson, J. (1989). Þættir sem áhrif hafa á árangur sauðfjársæðinga. Aðalritgerð við Búvísindadeild Bændaskólans á Hvanneyri, 36 bls. (In Icelandic).

Örnólfsson, E.K., Jónmundsson, J.V., Thorgeirsson, S. and Eythórsdóttir, E. (2007). Kjötgæði, árangur í ræktun. *Fjölrit LBHÍ nr. 14. Íslensk búfjárrækt. Málstofa til heiðurs Hjalta Gestssyni níræðum, Hótel Sögu, Reykjavík, 17. nóvember 2006*, 63-70. Ritstjóri: Ólafur R. Dýrmundsson, Landbúnaðarháskóli Íslands, 108 bls. (ISSN 1670-5785, in Icelandic).