4

ARTIFICIAL INSEMINATION

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The techniques and application of artificial insemination (AI) have changed considerably since it was first advocated as a practical proposition by the Japanese workers, Ito *et al.* (1948) over thirty years ago. Although Polge (1956) described the techniques necessary for the field application of AI in some detail no real development of commercial services took place until Rutgers (1966) reported a marked increase in the use of AI in Holland (120 000 inseminations per year) following a bad outbreak of foot and mouth disease in 1962. In the last five years there has been a marked increase in the development of field AI services in Holland and certain other countries (Denmark and the Democratic and Federal Republics of Germany).

Functions of AI

It is important that any review of AI should include, if only briefly, some reference to the current reasons for AI development, which are reflected in the AI services provided, and also the future needs of the pig industry. These reasons, which are listed below, vary in importance from country to country.

Genetic improvement of livestock

In all species AI enables superior tested sires to be used to a much greater extent than would be possible with natural mating. In the case of pigs the primary function of the AI service is (a) to provide a wider variety of new genes for herds at 'nucleus' level thus enabling greater selection intensity to be practised, and (b) to produce replacement breeding stock and, in certain situations, slaughter generation stock in commercial herds.

Maintenance of high health status

If herds are to make genetic progress fresh genetic material has to be introduced but this immediately increases the risk of introducing disease into the herd. However, this risk can be minimized, if not eliminated, by the use of AI (Reed, 1978; Larsen *et al.*, 1978; Pursel *et al.*, 1980b).

Adoption of batch farrowing procedures

Use of batch weaning, a necessity in large herds, means batch serving of sows with periods of heavy use of boars. Supplementation of boar services with AI can prevent overuse of boars thus enabling services to be restricted to four or five per week for each boar. AI could have an important role in conjunction with oestrous synchronization if the use of compounds such as the progestagen allyl trenbolone (RU-2267, altrenogest) described by Martinat-Botte *et al.* (1980) and Pursel *et al.* (1980a) were to give acceptable results under commercial conditions.

Reduction of service costs

In countries with high density pig populations, notably Holland and Denmark, AI centres have been able to offer a service at a lower cost than for natural service (Willems, personal communication).

International exchange of genetic material

The high cost of transporting live animals long distances by air, coupled with the problem of health certification, have stimulated a limited but increasingly important use of AI. Liquid semen has been used in certain situations but where the semen has to be quarantined to meet health regulations or is likely to be exposed to extremes in ambient temperature, the use of frozen semen can be justified in spite of the higher costs and lowered conception rates associated with present procedures (L.A. Johnson, 1980).

Current AI usage

The development of AI in Europe has been reviewed by Willems (1977) and more recently on a world wide basis by Bonnadonna and Succi (1980) and Iritani (1980). Detailed figures for the use of frozen semen are also given in Iritani's paper. These reports together with those from more recent data are summarized in *Table 4.1.* Of the 34 countries for which figures are quoted, the largest use of AI is in the USSR (2.4 million animals), the German Democratic Republic (1.02 million) and China (970 000). However, AI is now also used extensively in Western Europe (1.66 million). These reports indicate that over 7 million animals are bred by AI annually; however, less than 20 000 inseminations are carried out with frozen semen.

Table 4.1 ESTIMATED WORLD PIG AI USAGE

Country	*Year*	*Total no. females served*	*Total no. inseminated*	*No. inseminated with frozen semen*
Australia[a]	1977/78	?	3000	Experimental
Austria[a]	1977/78	405742	50312	Experimental
Belgium[a]	1977/78	626000	11894	Experimental
Brazil[b]	1977	?	5950	?
Bulgaria[b]	1977	?	145193	?
Canada[c]	1978	?	15697	7000
China[d]	?	23000000	970000	Experimental
Czechoslovakia[a]	1977/78	525605	170000	Experimental
Denmark[e]	1979/80	1560000	525000	Experimental
Eire[f]	1979/80	?	3000	Experimental
Finland[a]	1977/78	122700	67945	Experimental
France[a]	1977/78	2400000	80000	800
Germany (DR)[a]	1977/78	1195900	1016515	Experimental
Germany (FR)[a]	1977/78	2309873	241034	Experimental
Great Britain	1979/80	1641600	55532	Experimental
Greece[a]	1977/78	600000	Exptl.	Experimental
Hungary[a]	1977/78	713000	232321	560
Japan[a]	1977/78	1850000	48000	Experimental
Korea[a]	1977/78	399000	78530	Experimental
Malaysia[b]	1977	?	3896	?
Netherlands[g]	1979/80	?	485922	Experimental
Norway[a]	1977/78	134000	65300	Experimental
Peru[a]	1977/78	352250	Exptl.	Experimental
Philippines[a]	1977/78	62500	62500	—
Poland[b]	1977	?	150431	?
Singapore[a]	1977/78	9370	7357	Experimental
Spain[a]	1977/78	1212000	35000	1000
Sweden[h]	1978/79	510000	20375	Experimental
Switzerland[a]	1977/78	?	17725	600
Thailand[a]	1977/78	2989751	6711	Experimental
Turkey[b]	1977	?	429361	?
USA[a]	1977/78	15000000	30000	9000
USSR[b]	1977	?	2400000	?
Yugoslavia[a]	1977/78	1406000	90696	Experimental

Source: [a]Iritani (1980); [b]Bonadonna and Succi (1980); [c]28th Report on AI in Canada (1978); [d]Peilieu *et al.* (1980); [e]Svineavl og produktion i Danmark (1980); [f]Smith, D.J., personal communication; [g]Willems, personal communication; [h]Johnson, E. (1980).

Type of AI service provided

Inseminator service

Initially virtually all inseminations outside Eastern Europe were carried out by technicians operating from AI centres or sub-centres, many of whom were simultaneously providing a service for cattle. In Western Europe the inseminator service is still the major one in use particularly in those countries with dense pig populations such as Denmark and Holland (Willems, 1977). Inseminations are increasingly being carried out mainly by specialist pig inseminators although half the countries have received support from the cattle AI services (Willems, 1977). However, in some countries inseminations are also carried out by self-employed inseminators.

Semen delivery service (SDS)

Since the early report of a Semen Delivery Service (SDS) in Britain in the middle 1960s (Melrose, Reed and Pratt, 1968), there has been a steady but slow expansion of this type of service under which semen is sent, on request, direct to producers who carry out their own inseminations. The advantages of such a service are:

(a) Liquid semen from a range of superior performance tested boars from all AI centres in a country can be made available on a nationwide basis instead of being restricted to the area covered by the centre's Inseminator Service.
(b) Two inseminations can be carried out at the optimum time in the oestrous period instead of one insemination at the time the inseminator happens to visit the farm. In such situations efficient producers can often achieve higher fertility results with inseminations carried out by themselves than with those performed by a trained inseminator from the AI centre.
(c) The risk of introducing disease into the herd is reduced because there is no movement of vehicles or personnel between farms as is the case with an Inseminator Service.
(d) The service is cheaper to operate because the potential for semen sales is nationwide and it eliminates the cost of labour and transport incurred by inseminators travelling to farms.

On the other hand, the difficulties in operating such a service cannot be overlooked, namely:

(a) Reliable transport facilities are essential to ensure that liquid semen reaches its destination within 24 hours.
(b) Users of the service need to be given adequate training. In some countries (Federal Republic of Germany, Denmark and Holland) AI centres stipulate that the producer must attend a short training course before being allowed to receive semen. This is not a requirement in the UK but one-day training courses are provided by certain centres.
(c) Producers lacking confidence can be reluctant to use the Semen Delivery Service but this can be overcome by training courses and demonstrations of the AI techniques.
(d) Arrangements for monitoring AI results are advisable to provide a means of assessing how effectively the service is being used by different herds.

'On farm' semen collection/insemination programmes

AI has been used on a 'within farm' basis for many years on the large state farms and combines in Eastern Europe but in recent years there has also been increased use by the large farms and breeding companies in other countries. Good fertility results can be obtained and little additional technical expertise is required in those situations where raw semen containing high spermatozoal numbers is used shortly after collection.

However, where it becomes necessary to dilute and store semen for some hours before use, some laboratory facilities are required which may be difficult for individual farms or breeding companies to justify financially. This problem has been overcome in Spain and the USA where AI centres provide diluent for organizations carrying out their own 'within farm' AI programmes.

Review of the technical aspects of AI in the light of field developments

HEALTH AND MANAGEMENT OF BOARS FOR AI

Health considerations

It is clear from earlier remarks that increased priority must be placed on the health status of the AI boar stud and on the conditions under which semen is collected, processed and distributed, by attention to the following factors:

(a) Screening of boars before entry and during a 28-day isolation period for those diseases for which there is a reliable diagnostic test supported by a satisfactory herd history. Such a list would include foot and mouth disease, swine vesicular disease (SVD), tuberculosis, brucellosis, leptospirosis, Aujeszky's disease and transmissible gastroenteritis (TGE). Screening of this nature is only possible when routine vaccination against the disease concerned is not practised.
(b) Introduction of boars into an isolation compound for one month prior to entry into the main stud and keeping the boars in the main stud strictly segregated from all other livestock.
(c) Maintenance of high standards of hygiene at semen collection.
(d) Addition of antibiotics to diluted semen to control non-specific bacteria which may be present in semen and which are sensitive to penicillin and streptomycin.

Methods of housing

Comparatively little attention has been paid to the specific needs of AI boar studs. The general principles covering the housing of sows are, of course, relevant to the boar but in those countries which experience high ambient temperatures it is particularly important that boars are kept in insulated housing as Wettemann *et al.* (1976) have shown that boars subjected to elevated temperatures (above 31 °C) showed impaired reproductive performance. More recently, Wettemann and Desjardins (1979) have suggested that the lowered male reproductive performance following heat stress is, in part, related to alterations in testicular endocrine function and in spermatid maturation.

Normally boars are kept singly but some AI centres have, for economy reasons, found it quite practical to keep two boars per pen. *Figure 4.1* shows a purpose-built house for 80 boars individually penned on a large AI centre in the Federal Republic of Germany.

Figure 4.1 Purpose-built house for 80 individually penned boars on a large AI Centre in the Federal Republic of Germany. By courtesy of Dr R. Hahn

Boar training

The great majority of boars can normally be trained for use in AI without difficulty as indicated by data for 394 boars which entered the two Meat and Livestock Commission (MLC) Pig Breeding Centres between 1964 and 1980 (*Table 4.2*). The percentage of boars successfully trained for AI under 10 months of age at entry (92%) was significantly higher ($P<0.001$) than boars 10–18 months at entry (70%). There was also a significant difference ($P<0.001$) in the percentage of 10–18 month old boars (70%) trained compared with the seven boars over 18 months of age at entry (0%). Significant differences between breeds were also noted, Large White boars being better than Landrace ($P<0.005$ for boars under 10 months of age at

Table 4.2 ANALYSIS OF BOARS TRAINED FOR AI AT DIFFERENT AGES AT ENTRY INTO AI CENTRE (1964–1980)

Breed	*Boars under 10 months at entry*			*Boars 10–18 months at entry*			*Boars over 18 months at entry*		
	Total no.	*No. trained*	*%*	*Total no.*	*No. trained*	*%*	*Total no.*	*No. trained*	*%*
Large White	171	167	98	9	9	100	1	–	0
Landrace	135	122	90	22	14	64	5	–	0
Hampshire	21	14	67	2	–	0	1	–	0
Other breeds (Welsh, Lacombe, BSB and Duroc)	23	20	87	4	3	75	–	–	–
TOTAL	350	323	92	37	26	70	7	–	0

Significance of differences in boar training: Boars (<10 months) versus boars (10–18 months), $P<0.001$; Boars (10–18 months) versus boars (>18 months), $P<0.001$; Large White boars (<10 months) versus Landrace boars (<10 months), $P<0.005$; Large White boars (10–18 months) versus Landrace boars (10–18 months), N.S.; Hampshire boars versus other breeds of boar, $P<0.05$.
From Meat and Livestock Commission.

Table 4.3 INCIDENCE OF BOARS WHICH MOUNTED AND EJACULATED AT FIRST INTRODUCTION TO DUMMY SOW (1964–1980)

Breed	*All boars trained for which data available*			*Trained boars, which were subsequently culled because of low libido*		
	Total no. trained	*No. trained at first attempt*	*%*	*Total no. trained*	*No. trained at first attempt*	*%*
Large White	161	113	70	5	3	60
Landrace	96	68	71	17[a]	9	53
Hampshire	13	4	31	2	–	0
Other breeds (Welsh, Lacombe, BSB and Duroc)	23	10	43	4	–	0
TOTAL	293	195	66	28	12	43

[a]Excludes six Landrace boars culled for low libido for which detailed training data not available.
Significance of differences in boars which mounted and ejaculated at first introduction to dummy sow:
Large White and Landrace v. all other breeds, $P<0.001$
Boars culled for low libido v. boars culled for other reasons, $P<0.05$.
From Meat and Livestock Commission.

entry). The Hampshire breed was significantly more difficult to train than the other breeds ($P<0.05$ for boars under 10 months of age at entry). MLC data in *Table 4.3* show that when boars were introduced to the dummy sow for the first time 195 boars (66%) mounted and ejaculated successfully. The Large White and Landrace boars were significantly better than the other breeds (Hampshire, Welsh, Lacombe, British Saddleback (BSB) and Duroc) in this respect ($P<0.001$). Of the trained boars, which were subsequently culled because of low libido, only 12 (43%) mounted and ejaculated at the first introduction to the dummy sow compared with 195 (66%) eventually culled for reasons other than low libido ($P<0.05$).

Collection technique

It is generally accepted that the most satisfactory method for collecting semen is by fixation of the penis by the hand method using a dummy sow as a teaser. However, the shape and size of dummy sows used varies widely as also does the semen collection site. Some AI centres favour a separate collection pen while others use a portable dummy sow in the boar's pen.

Collection frequency and semen production

This subject has been reviewed by du Mesnil du Buisson and Paquignon (1977). In our own experience the optimum collection frequency seems to be once every four or five days although du Mesnil du Buisson and Paquignon have suggested that semen collection can be increased to more than once or twice a week without markedly affecting the amount of spermatozoa collected from each boar. However, Swierstra and Dyck (1976) found that when ejaculates collected at 72 and 24 hour intervals were compared, the former ejaculates contained three times as many spermatozoa. It is clear that there is a considerable variation between boars in the number of spermatozoa produced, which is thought to be influenced mainly by the size of the testes (du Mesnil du Buisson and Paquignon, 1977). Hemsworth and Galloway (1979) have reported that spermatozoa numbers in the sperm-rich fraction of the ejaculate can be significantly increased in the short term by allowing the boar to have a false mount and thereafter restraining it in an adjacent pen for two minutes before collecting the semen.

SEMEN PRESERVATION

Liquid semen

Diluents in current use are listed in *Table 4.4* and recent comparative fertility results, where available, are summarized in *Table 4.5*. Egg yolk/glucose, one of the original diluents to be used in the field, is now only

Table 4.4 DILUENTS CURRENTLY USED FOR STORING BOAR SPERMATOZOA IN THE LIQUID STATE

Diluent	*Reference*
Egg yolk/Glucose	Aamdal and Hogset (1957)
IVT (Illinois Variable Temperature)	VanDemark and Sharma (1957); Modified for pigs by du Mesnil du Buisson and Jondet (1961)
Kiev (also known as Plishko, Varohm, Merck, GCHC, Guelph or EDTA)	Plishko (1965)
Kharkov (also known as Trilon B)	Serdiuk (1968)
BL-1	Pursel, Johnson and Schulman (1973)
SCK7 (Modified IVT)	Developed by Walls Meat Co. Ltd. (1975) (Walters, personal communication)
Zorlesco	Gottarai, Brunel and Zanelli (1980)

used in Belgium (Willems, 1977). IVT (Illinois Variable Temperature) diluent which was used extensively in Europe in the sixties and early seventies has been largely superseded by Kiev diluent. It can be seen in *Table 4.5* that both diluents give very similar fertility results (Larsson, Swensson and Wass, 1979; Kuiper and de Haas, 1980; Reed, MLC unpublished data) but the Kiev diluent is much simpler to prepare and, for this reason, is more widely used by commercial AI centres. There appears to be little difference in fertility between first and second day semen but L.A. Johnson *et al.* (1980) reported that third day semen gave a significantly lower farrowing rate. BL-1 diluent, which was first described by Pursel, Johnson and Schulman (1973), has been reported to give significantly lower fertility results than Kiev diluent (Paquignon *et al.*, 1980b; L.A. Johnson *et al.*, 1980). Where 1–3 day old Kiev diluted semen has been compared with 4–6 day old SCK7 diluted semen, better fertility results have been obtained with Kiev diluent (Swensson, 1977; Paquignon *et al.*, 1980b) although somewhat more encouraging results were reported for SCK7 diluent by Fischer-Pereira Cunha (1979). However this diluent has only been used to a very limited extent and there is no published evidence

Table 4.5 COMPARISON OF FERTILITY RESULTS OBTAINED WITH LIQUID SEMEN DILUENTS

Reference	*Diluent*	*Semen age*	*No. animals*	*Success rate (%)*	*Average no. pigs born*
Larsson *et al.* (1979)	IVT	0–12 hours	158	63.3[a]	11.4
		13–36 hours	455	64.8[a]	11.4
		37–60 hours	201	63.7[a]	11.9
		Total	814	64.3[a]	
	EDTA Glucose (Kiev)	0–12 hours	155	64.5[a]	11.0
		13–36 hours	421	60.8[a]	11.6
		37–60 hours	189	65.1[a]	11.2
		Total	765	62.6[a]	
Kuiper and de Haas (1980)	IVT	1st and 2nd day	1113	78.1[a]	10.92
	Kiev	1st and 2nd day	921	79.2[a]	10.84
Reed (1981)[c]	IVT	1–4 days	744	70.8[a]	9.9
	EDTA (Kiev)	1–4 days	694	71.6[a]	9.7
Paquignon *et al.* (1980b)	Guelph (Kiev)	1st day	42	69.1[a]	10.2
		2nd day	88	76.2[a]	9.6
		3rd day	48	68.8[a]	11.7
		4th day	48	81.3[a]	8.8
		5th day	18	61.2[a]	7.8
		Total	178	72.5[a]	10.3
	BL-1	1st day	38	63.2[a]	11.4
		2nd day	78	70.5[a]	10.8
		3rd day	35	60.0[a]	11.0
		Total	151	66.2[a]	11.0
Johnson *et al.* (1980)	Kiev	1–3 days	1280	69.3[a]	10.1
	BL-1	1–3 days	1283	60.5[a]	9.8
	Kiev & BL-1	1st day	825	70.2[a]	10.4
		2nd day	891	65.9[a]	9.8
		3rd day	847	58.7[a]	9.5
Paquignon *et al.* (1980b)	BL-1	1st day	27	66.7[b]	
		2nd day	51	70.6[b]	
		3rd day	16	81.2[b]	
		Total	94	71.3[b]	
	SCK7	4th day	27	81.5[b]	
		5th day	27	48.2[b]	
		6th day	31	61.3[b]	
		7th day	19	63.2[b]	
		Total	104	63.5[b]	
Fischer-Percira Cunha (1979)	Kiev	1st day	189	62.96[a]	10.3
		2nd day	201	64.18[a]	9.9
		Total	390	63.69[a]	10.1
	SCK7	1st day	111	69.36[a]	9.9
		2nd day	121	66.11[a]	9.1
		3rd day	110	57.27[a]	9.7
		4th day	129	68.99[a]	9.6
		5th day	91	59.34[a]	8.4
		Total	562	64.59[a]	9.4
Swensson (1977)	IVT	1–3 days	124	65.3[a]	10.9
	SCK7	5–6 days	116	44.8[a]	9.1
	IVT	1–3 days	504	88.3[b]	
	SCK7	4th day	143	83[b]	
		5th day	170	82[b]	
		6th day	189	80[b]	

[a]Percentage farrowing rate.
[b]Non-return at 54 days.
[c]MLC unpublished data.

to demonstrate its superiority over other diluents in terms of fertility results with semen older than three days.

In a recent preliminary report Gottarai, Brunel and Zanelli (1980) gave details of a new diluent which could be used for storing semen for 8–12 days but no fertility data were given to support this claim. On the basis of the above reports and experience with the MLC AI services, Kiev would seem to be the diluent of choice for use under commercial conditions. Semen extended in this diluent can be used for up to three days with acceptable fertility results and use of semen stored for up to five or six days can be justified in export situations or where nucleus breeders need to nominate particular boars even though the use of such semen is likely to be associated with lower fertility.

Frozen semen

Numerous reports have been published since Polge, Salamon and Wilmut (1970) first obtained successful fertility results with frozen semen. Various methods developed by different groups of workers have been summarized by Graham, Crabo and Pace (1978), Larsson (1978), Pursel (1979) and L.A. Johnson, (1980). The main steps in the different procedures described are somewhat similar in that they all involve a period of equilibration, concentration by centrifugation, addition to diluent and glycerol at some stage prior to freezing in pellets or straws. Recent fertility results obtained by different workers for the main methods described were summarized by L.A. Johnson, (1980) as shown in *Table 4.6*. Reasonable

Table 4.6 SUMMARY OF FERTILITY RESULTS OBTAINED WITH DIFFERENT IMPROVED FREEZING PROCEDURES

Freezing procedure	*No. animals*	*% pregnant*	*Litter size*
Beltsville method	378	53	8.2
French procedure	293	58	8.8
German method	805	65	8.5

From Johnson, L.A. (1980)

results have been obtained with all the methods listed, but the Beltsville method (Pursel and Johnson, 1975) seems to have been favoured by the commercial AI organizations using frozen semen under field conditions in the USA, Canada and Spain. The processing and freezing procedures are summarized below:

Equilibration at 20° for 2 hours
↓
Removal of seminal plasma by centrifugation
↓
Addition of BF5 diluent
↓
Cool to 5 °C
↓
Addition of further BF5 diluent and glycerol
↓
Freeze 0.2 ml pellets on dry ice
↓
Liquid nitrogen

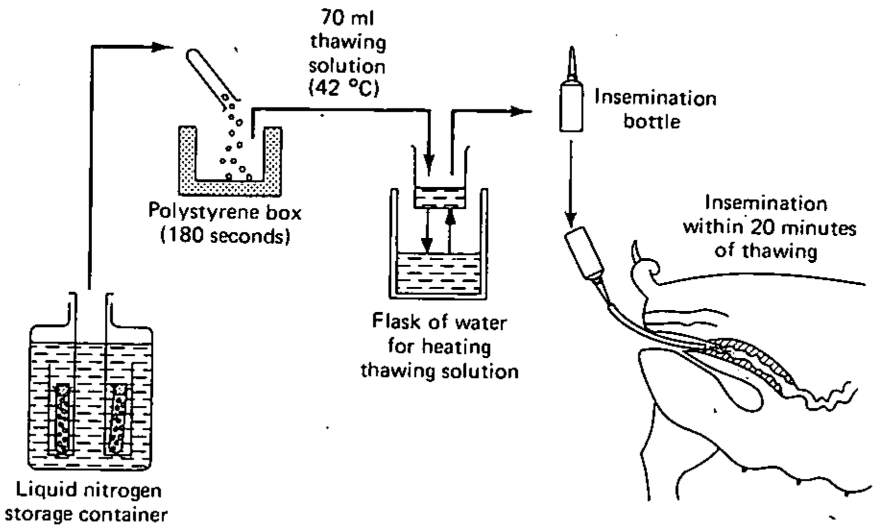

Figure 4.2 Thawing procedure (based on Beltsville technique)

Pursel, Schulman and Johnson (1978) showed that Orvus ES Paste, which is one of the components of BF5 diluent, has a beneficial effect on semen preservation. The thawing procedure which involves the addition of 70 ml Beltsville thaw solution at 42 °C, is summarized in *Figure 4.2*. The Beltsville procedure has also been used in Britain for imported and exported semen. Interim results for these inseminations together with other field results for which Meat and Livestock Commission has been responsible are summarized in *Table 4.7*. It is of interest to note that there is comparatively little difference in fertility between pigs inseminated by full-time inseminators and those by producers doing their own inseminations. The results are also in agreement with the conception rate of 39% (and 8.8 pigs born alive) (321 animals) obtained by the Animal Breeding Research Organisation, Edinburgh with frozen semen imported from

Table 4.7 FERTILITY RESULTS OBTAINED FROM FROZEN SEMEN 1975–1980 (a) IN THE UK; (b) EXPORTED

Category	*No. breeders*	*No. pigs inseminated*	*No. pregnant*	*Conception rate (%)*	*Average no. pigs born*
(a) MLC SEMEN USED IN UK					
Pigs inseminated on farms by MLC inseminators	8	67	30	45	6.1
Pigs inseminated on farms by breeders	4	34	14	41	6.9
(b) EXPORTED/IMPORTED SEMEN					
Pigs inseminated with MLC exported semen by overseas breeders	5	160	54	34	6.6
Pigs inseminated with semen imported from USA by UK breeders	7	178	53	30	7.4

North America (Will, personal communication). They also confirm the findings of Johnson *et al.* (1980) who found that conception rates and mean number of pigs born alive achieved with frozen semen (47% and 7.1 respectively) were considerably lower than those obtained with liquid semen (79% and 9.9) from the same boars. Some of the factors influencing conception rates of pigs inseminated with frozen semen under commercial conditions have been evaluated by Paquignon *et al.* (1980a).

The reports previously listed, coupled with our own experience, have shown that frozen semen is unlikely to be used on a widespread commercial scale in the foreseeable future because of the following shortcomings:

(a) The high spermatozoal dose (5×10^9 spermatozoa per insemination) needed to achieve reasonable fertility under field conditions markedly increases the cost of providing a frozen semen service compared with that for liquid semen.
(b) Laboratory assessments of semen quality are of very limited value in predicting a boar's potential fertility.
(c) There is a considerable variation in the freezing ability between boars.
(d) The semen processing procedure is complicated and time-consuming compared with the procedures used for liquid semen.
(e) Producers carrying out their own inseminations need to have ready access to liquid nitrogen supplies.
(f) The timing of insemination(s) in relation to ovulation and hence oestrus detection is very much more critical if acceptable fertility results are to be obtained (Larsen, 1976).
(g) Average conception rates and litter sizes achieved with frozen semen are lower than those obtained with liquid semen.

OESTRUS DETECTION PROCEDURES

A positive response to the back pressure test in the absence of the boar has, for many years, been regarded as the optimum method for identifying the correct time for a single insemination within the oestrus. The difficulty of eliciting a positive response in all animals to the back pressure test in the absence of the boar has led to the development of synthetic boar odour aerosol to elicit the physical symptoms of oestrus in such animals (Melrose, Reed and Patterson, 1971; Reed, Melrose and Patterson, 1974). These aerosol packs† have been extensively used in those countries with small herds or where wide use of an Inseminator Service has been made.

Schilling and Rostel (1964) reported that the lowest pH values of vaginal mucus secretion were found in mid-oestrus. An instrument‡ relying on this principle has been marketed by a commercial organization who claim that it can be used to accurately pinpoint the optimum time for insemination. However, as no data appear to have been published on the use of this instrument it is not possible to evaluate the effectiveness of the technique as an aid in timing inseminations correctly.

†'Boar Mate', Antec International Ltd., Sudbury, England.
‡'Walsmeta', Masterbreeders (Livestock Development) Ltd., Basingstoke, England

Under Semen Delivery Service conditions the use of a boar for heat detection is the method of choice because semen must be ordered sufficiently early to reach the farm to enable the inseminations to be carried out at the correct time. Thereafter two inseminations can be carried out at an interval of 8–16 hours without further recourse to oestrus detection.

Table 4.8 RECOMMENDED PROCEDURE FOR OESTRUS DETECTION

Type of AI service	*Method of oestrus detection*	
	Boar available	*No boar available*
'Inseminator' Service (One insemination/oestrus)	Boar to detect oestrus onset. Back pressure in absence of boar to time insemination.	Back Pressure Test + Boar Odour Aerosol
'Semen Delivery' Service (Two inseminations/oestrus)	Boar to detect oestrus onset.	Back Pressure Test + Boar Odour Aerosol

The most reliable routine for oestrus detection depends, therefore, on the availability of a boar and recommendations for use in relation to the type of AI service available and frequency of oestrus checking as indicated in *Table 4.8.*

INSEMINATION TIMING

Polge (1969) stated that the principal factor governing fertility and litter size was the relationship between time of insemination (or mating) and the time of ovulation during oestrus. He reported that ovulation occurred between 36 and 50 hours after the onset of heat and also pointed out that injection of human chorionic gonadotrophin (HCG) at around the onset of oestrus would result in ovulation 40–42 hours later. Since then Niswender, Reichert and Zimmerman (1970) have shown that the LH peak coincided with the observed onset of oestrus as measured by boar acceptance. However, recent work by Foxcroft (personal communication) suggests that

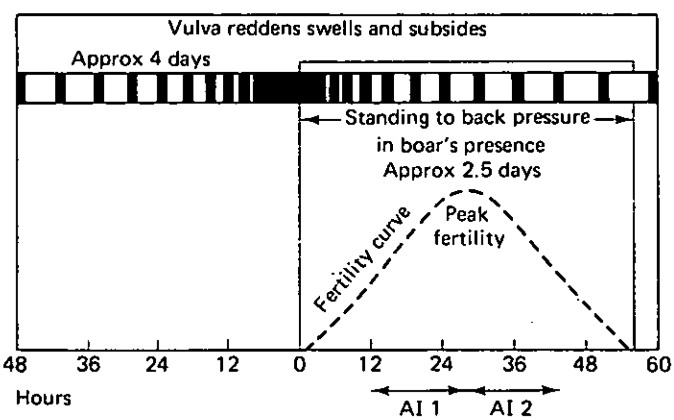

Figure 4.3 Recommended times for insemination

the LH surge might vary from as much as 12 hours before to 12 hours after the onset of boar acceptance. This would seem to suggest that, where possible, there is a strong case for carrying out more than one insemination in each oestrus, even though Boender (1966) has shown that inseminations carried out very early and very late in oestrus result in low fertility. *Figure 4.3* shows the timing recommended to producers using the MLC Semen Delivery Service. In practice this is governed by the method of semen dispatch to the farm as indicated in *Table 4.9*. It should be noted that the interval between inseminations for a postal dispatch is likely to be only 7–8 hours (09.00 and 16.30 hours on day 2) compared with 16 hours for a rail dispatch (16.30 hours on day 1 and 09.00 hours on day 2) because postal dispatches take 24 hours to reach their destination compared with arrival the same day for the other two dispatch categories. Data for the MLC Semen Delivery Service are shown in *Table 4.10*. Although there were significant differences for semen dispatched by the different methods ($P<0.001$ for semen collected versus rail dispatch and $P<0.001$ for rail dispatch versus postal dispatch), it cannot be concluded that insemination timing was the sole reason for the lower fertility because fertility levels also seem to be influenced by semen age at dispatch ($P<0.01$ for day 1 versus day 2 semen) and also possibly by month of the year (see *Figure 4.6*). There is also a need to determine the influence of 'within herd' effects

Table 4.9 TIMES CURRENTLY RECOMMENDED FOR INSEMINATION OF PIGS IN HERDS USING MLC SEMEN DELIVERY SERVICE IN BRITAIN

Animal first stands to boar	*Method of semen dispatch*	*First insemination*	*Second insemination*
Morning Check (Day 1)	Rail Collected from AI Centre	p.m. Day 1	a.m. Day 2
	Post	a.m. Day 2	p.m. Day 2
Afternoon Check (Day 1)	Collected from AI Centre	p.m. Day 1	a.m. Day 2
	Rail Post	a.m. Day 2	p.m. Day 2

Table 4.10 FERTILITY RESULTS RELATED TO METHOD OF SEMEN DISPATCH AND AGE OF SEMEN AT DISPATCH (SDS 1977–79)

Dispatch method	*Semen age at dispatch*	*No. known results*	*No. pregnant*	*Conception rate (%)*	*Average no. pigs born*
Collected from AI Centre	1st day	1902	1507	79	10.4
	2nd day	253	199	79	10.1
	3rd day	13	11	85	11.8
Rail	1st day	11 107	8164	74	10.1
	2nd day	1805	1287	71	10.2
	3rd day	52	34	65	9.6
Post	1st day	9598	6708	70	9.6
	2nd day	415	267	64	9.7
	3rd day	–	–	–	–

Statistical analysis based upon data for semen ages at dispatch Days 1 and 2 only.
Significance of differences in % success rate:
'Dispatch Day 1' versus 'Dispatch Day 2', $P<0.01$
'Semen collected' versus 'Dispatch by rail', $P<0.001$
'Dispatch by rail' versus 'Dispatch by post', $P<0.001$
From Meat and Livestock Commission.

Table 4.11 COMPARISON OF FERTILITY RESULTS FOR SOWS INSEMINATED TWICE AND THREE TIMES IN EACH OESTRUS (INTERIM RESULTS)

Duration of oestrus (hours)	*No. inseminations per oestrus*	*No. sows*	*No. unknown results*	*No. known results*	*No. pregnant*	*Conception rate (%)*	*No. pigs born*	*No. litters*	*Average no. pigs born*
>40	Triple AI (Trial)	25	-	25	25	100	295	24	12.3
	Double AI (Control)	25	-	25	23	92	237	22	10.8
<40	Double (Non trial AI)	82	2	80	66	83	659	65	10.1
Total		132	2	130	114	88	1191	111	10.7

Significance of differences in % conception rate:
- Triple AI versus Double AI (>40 hr oestrus) N.S.
- Triple AI versus Double AI N.S.

Significance of differences in litter size:
- Triple AI versus Double AI (>40 hr oestrus) N.S.
- Triple AI versus Double AI $P<0.01$

From Meat and Livestock Commission

because different herds not only use different methods of semen dispatch and oestrus detection but also sometimes anticipate the onset of oestrus and do not necessarily use the semen on the same day as its arrival.

Under field conditions in Britain some producers mate animals, which are in oestrus for three days or more, a third time. *Table 4.11* shows the interim results of a small MLC trial carried out on one farm with very good records where alternate sows in oestrus for more than 30–40 hours were inseminated twice or three times at intervals varying from 8–16 hours. Fertility results are also given for sows in oestrus less than 40 hours, which were artificially inseminated over the same period. No significant differences in conception rate or litter size were observed between the two sow groups in oestrus for over 40 hours but if all sows are included, those inseminated three times had a significantly better litter size ($P<0.01$) than sows inseminated only twice during oestrus. Further data are required before definite conclusions can be drawn but these results are in agreement with those found by Tilton (personal communication). Although Hunter (1975) has reported that an adequate sperm reservoir can be maintained in the utero-tubal junction for at least 24 hours, it is possible that an adequate supply of spermatozoa cannot be maintained for the same period under commercial AI conditions using limited spermatozoal numbers ($1-3 \times 10^9$) compared with natural mating conditions involving higher spermatozoal numbers.

There is also evidence that mixed semen from different boars results in better fertility (Pacova and Dupal, 1978) but this is unlikely to be acceptable to producers using AI to produce replacement breeding stock. However this procedure could have some application in large commercial herds making extensive use of AI for the production of slaughter generation pigs.

INSEMINATION TECHNIQUE

The spermatozoal dose and inseminate volume used for liquid semen under commercial conditions varies from 1×10^9 to 3×10^9 and 50 to 150 ml respectively. In some countries additional diluent is added to the diluted semen prior to insemination. It is now also usual for semen to be transported in disposable polythene bottles with spouted tops, the end of which is cut off prior to being attached to the catheter. Different countries tend to favour different types of catheter but the version most widely used is the spiral catheter evolved by Melrose and O'Hagan (1961). It is particularly favoured by producers carrying out their own inseminations because they can readily recognize when it is in the correct position for insemination from its characteristic 'locking' action in the posterior folds of the cervix. Attempts are being made to produce a disposable spiral catheter at an economic price.

FERTILITY LEVELS

Conception rates reported for AI services from different countries vary widely (60–90%) depending on the criteria used for measuring fertility, type of service provided, management and size of herd, number of inseminations per oestrus and sow parity. The detailed recording and monitoring carried out in herds using the MLC Semen Delivery Service has allowed an assessment of the factors that appear to influence field fertility results. The main factors are summarized in *Tables 4.12* to *4.14* and *Figures 4.4* to *4.6*.

In *Figure 4.4* it can be seen that there was a marked improvement in the average conception rate achieved during the first seven years of the service

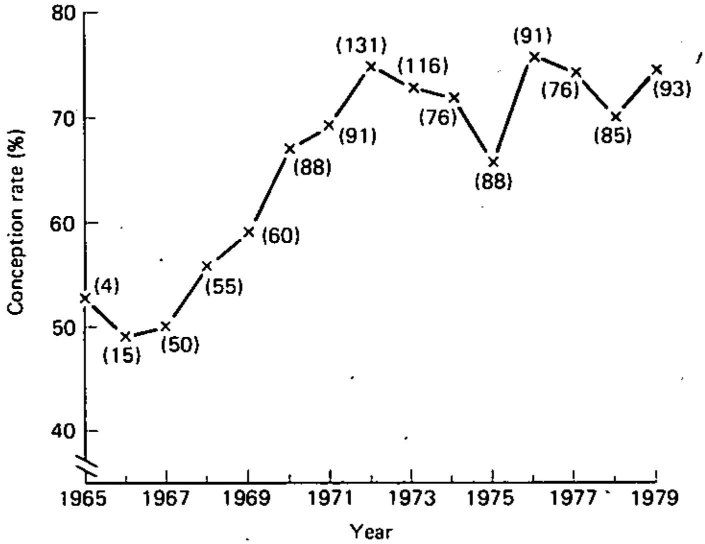

Figure 4.4 Mean annual percentage conception rate for Semen Delivery Service 1965–1979 (known results in hundreds). From Meat and Livestock Commission

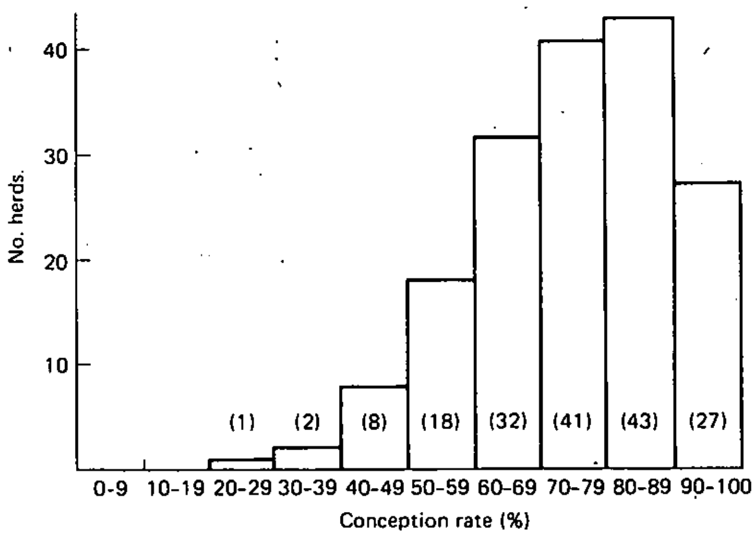

Figure 4.5 Variation in annual herd percentage conception rate levels (based on herds with over 10 known results for SDS 1979–1980). From Meat and Livestock Commission

Table 4.12 HERD CATEGORIES USING THE MLC SEMEN DELIVERY SERVICE (1979–1980)

Herd category	*No. herds*	*No. semen doses dispatched*	*No. known results*	*No. pregnant*	*Conception rate (%)*	*Average no. pigs born*
Nucleus and reserve nucleus herds	51	1098	550	369	67	10.2
Breeding companies	25	590	363	251	69	9.9
Commercial herds	935	13171	7848	5927	76	10.2
TOTAL	1011	14859	8761	6547	75	10.2

Difference in % conception rate for commercial herds versus other herd categories is significant ($P<0.001$)
From Meat and Livestock Commission.

Table 4.13 FERTILITY RELATED TO SEMEN USAGE (SDS 1979–80)

Herd annual semen usage (doses)	*No. herds*	*No. doses dispatched*	*No. known results*	*No. pregnant*	*Conception rate (%)*	*Average no. pigs born*
1–4	517	1151	686	458	67	10.2
5–9	195	1260	710	494	70	10.4
10–19	141	1906	1133	813	72	10.2
20–49	102	3204	1763	1287	73	10.0
50–99	32	2204	1346	1036	77	10.2
100–249	16	2555	1394	1087	78	10.5
250 or over	8	2579	1729	1372	79	9.7
TOTAL	1011	14859	8761	6547	75	10.2

Increasing % conception rate with usage is highly significant ($P<0.001$).
From Meat and Livestock Commission.

Table 4.14 FERTILITY RELATED TO HERD SIZE (SDS 1979–80)

Herd size (sows/gilts of breeding age)	*No. herds*	*No. known results*	*No. pregnant*	*Conception rate (%)*	*Average no. pigs born*
1–4	234	425	248	58	10.5
5–19	116	324	215	66	10.7
20–49	138	760	571	75	10.4
50–99	160	1304	999	77	10.3
100–249	203	2713	2053	76	10.4
249–499	40	924	689	75	10.1
500 or over	19	2063	1588	77	9.5
Herd size unknown	101	248	184	74	10.0
TOTAL	1011	8761	6547	75	10.2

Herds with under 20 sows/gilts have significantly lower % conception rate than herds with over 20 sows/gilts ($P<0.001$).
From Meat and Livestock Commission.

Table 4.15 FERTILITY RELATED TO PARITY (SDS 1979–80)

Parity	*No. known results*	*No. pregnant*	*Conception rate (%)*	*Average no. pigs born*
Sows	5532	4375	79	10.4
Gilts	1136	787	69	9.0

Sows have significantly higher % conception rates than gilts ($P<0.001$)
From Meat and Livestock Commission.

(1965–72) but little improvement has been obtained in the last seven years. *Table 4.12* shows that commercial herds, which accounted for 89% of the semen demand, achieved better farrowing rates than nucleus and breeding company herds ($P<0.001$). The distribution of herd fertility levels for those herds with more than 10 known results is shown in histogram form in *Figure 4.5*. It can be seen that a high proportion of herds achieve conception rates in excess of 70%. Herd conception rates, as one would expect, are related to AI usage (*Table 4.13*). The 56 herds (6%) using over 50 doses of semen per annum account for 49% of the semen uptake—an important factor when considering priorities for field advisory work. *Table 4.14* shows that herds with under 20 sows and gilts of breeding age had significantly lower fertility than herds with over 20 animals of breeding age ($P<0.001$). In Britain producers carrying out their own inseminations are sometimes deterred from using artificial insemination on maiden gilts because the technique is said to be more difficult and associated with lower fertility than with sows. MLC data (*Table 4.15*) show that the average conception rate and total number of pigs born was 79% and 10.4 pigs for sows and 69% and 9.0 pigs for gilts respectively. Although the differences were significant ($P<0.001$), producers are still justified in using a semen delivery service for maiden gilts particularly if the objective is to produce replacement breeding stock.

It has already been mentioned that high ambient temperatures can have an adverse effect on boar fertility. In addition to this factor, semen used in the Semen Delivery Service can be in transit for up to 24 hours and stored for up to another 48 hours under varying conditons on farms. Even in temperate countries such as Britain the dispatch of semen by public transport can result in semen being exposed to a wide range of environmental temperatures even though it is packed in expanded polystyrene boxes. Liquid semen diluents in current use such as IVT and Kiev do not give ideal protection to semen under wide variations in ambient temperature. Analysis of ten years MLC data for the Semen Delivery Service showed that there is a small but real underlying seasonal trend in mean conception rate and litter size numbers although there is a considerable

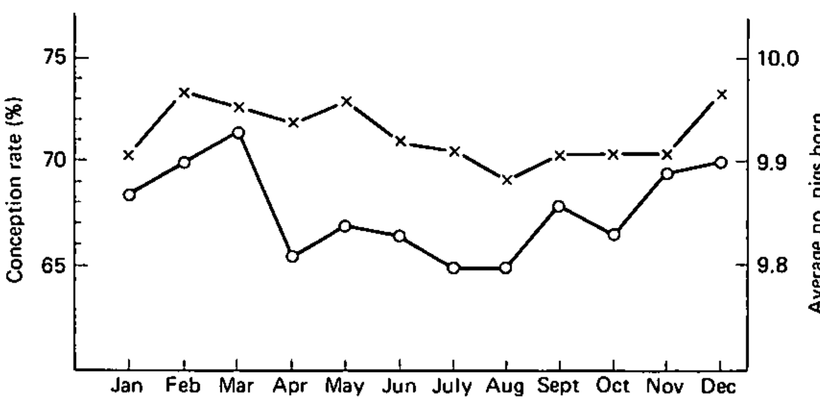

Figure 4.6 Mean seasonal variation in percentage conception rate (×——×) and average number of pigs born (O——O) for SDS 1970–1979 inclusive (92 000 results). From Meat and Livestock Commission

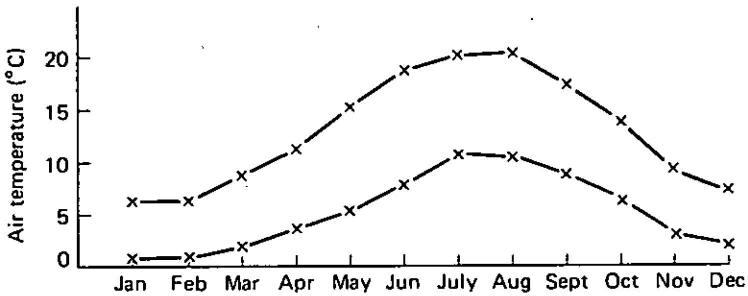

Figure 4.7 Average daily mean maximum and minimum air temperatures recorded by Meteorological Office at Cawood, near Selby, 1970–1979 inclusive

variation between individual years. In general there is a tendency for conception rates to decrease as temperature increases in the summer months and to increase as temperature decreases in the winter months (*Figure 4.6*). However the range of average daily mean maximum and minimum air temperatures recorded near the MLC Centre was small (*Figure 4.7*) compared with countries èxperiencing greater extremes in climate.

TRAINING, ADVISORY AND MONITORING PROCEDURES NECESSARY FOR PRODUCERS USING A SEMEN DELIVERY SERVICE

In those situations where AI organizations provide Semen Delivery Service facilities for producers, adequate education, training in techniques and monitoring facilities must also be available to ensure satisfactory fertility results irrespective of whether liquid or frozen semen is used. Three important aspects are discussed below.

Provision of explanatory literature

All prospective users should be provided with clear instructions covering the administrative and technical procedures involved to enable them to decide if they wish to use the service available.

Provision of training facilities

The type of training provided varies. Some organizations make it a condition that producers undergo a short training course usually of one day (North America and Denmark). Other organizations prefer producers to use the Inseminator Service before using the Semen Delivery Service (Holland and Bavaria, Federal Republic of Germany). In Britain, the MLC have organized one-day group training courses, given individual 'on farm' training for the large herds or provided training sessions at AI centres, but course attendance is not a pre-requirement for use of the service. Results from the MLC Semen Delivery Service would suggest that 'on farm' training or attendance at a one-day training course is quite sufficient for the producer of average ability to acquire the necessary confidence and experience to use AI satisfactorily. However it is essential that farm personnel, who will do the actual technical work, receive the training rather than the owner. The use of frozen semen does not require a longer training period but strict attention to detail especially the timing of the inseminations is essential.

Monitoring AI fertility results

Monitoring fertility results in herds making regular use of the service is essential. The availability of computer facilities permits immediate access to the appropriate data on a regular basis. A permanent herd history record for regular AI users should also be maintained at the centre. In the MLC service a report is completed at the time of the first herd visit to show herd size and herd breeding policy, personnel involved, heat detection, natural service and insemination procedures. A confidential assessment of the herd's capabilities for the use of AI and recommendations, if any, are also recorded. This record is updated at subsequent visits which, in the case of regular users (over 20 doses per annum), is made about once per year.

Some AI centres in Britain and Holland consider it is also advisable that progeny of AI boars be monitored for developmental abnormalities. Where the incidence of an abnormality becomes unacceptably high the boar is culled. Atresia ani, scrotal hernias and congenital splay legs are examples of the more common abnormalities observed. Such monitoring procedures can, however, be carried out more effectively through an Inseminator Service where AI personnel regularly visit the herds of AI users, than through a Semen Delivery Service.

Future developments

The high costs of the inseminators' time and travelling coupled with health considerations have favoured the development of a Semen Delivery Service under British conditions and more recently in certain European countries. However in some countries (USA) the lack of suitable transport facilities has ruled out the possibility of any widespread use of a Semen Delivery Service unless frozen semen can be used. In areas of dense pig population where mileage travelled per insemination is low, an Inseminator Service with a single insemination is used routinely, but in some situations technicians inseminate at the time of a visit and leave a second dose for the producer to inseminate later, thereby giving the fertility advantage from a double insemination. This practice would become more attractive if disposable insemination equipment were inexpensive and readily available. However specific guidance could be given to all producers on oestrus detection frequency and the optimum number and timing of inseminations particularly in large herds with intensively managed sows where accurate oestrus detection can be difficult. The advice given has often to be varied according to such individual herd circumstances.

Further improvements in semen storage techniques would enable a more efficient AI service to be provided for producers. In the case of liquid semen, the Semen Delivery Service would have a much wider appeal if diluted semen could be used for up to seven days without any drop in fertility. Semen could then be dispatched on a weekly basis thereby reducing the cost and possible inconvenience of semen transport.

It has already been established that there is a use for frozen semen in import/export situations in spite of the high costs associated with current techniques. These costs would be considerably reduced if the spermatozoa

Figure 4.8 Dilution of boar semen with Kiev extender in plastic bag also used for the collection of semen. By courtesy of Dr R. Hahn

numbers/dose could be considerably reduced without lowering fertility and if poor 'freezer' boars could be quickly identified from laboratory assessments of semen quality.

The marked expansion of AI in certain countries to the stage where a limited number of AI centres are now using more than 100 000 doses/year has provided a stimulus to streamline various AI centre procedures, especially semen collection, dilution and dispatch techniques. A good example of this trend is at the Neustadt AI centre in the Bavarian area of Germany where diluent is added to semen in the same plastic bag in which the semen is collected (*Figure 4.8*). More attention will also have to be paid to the design of large scale boar accommodation and overall design of AI centres in view of the increasing importance of health. In the latter respect AI centres in most countries are already subject to certain government AI regulations. In addition to using separate staff, health control would also be improved if premises used by field technicians were separate from the boar stud and the facilities used for collection and dilution of the semen. Close control of AI centres in this way may help to stimulate AI demand when the European Economic Community introduces the swine fever eradication programme in mid-1981. Independent quarantine facilities for semen will also become necessary if the demand for frozen semen should develop. However the main factor influencing the type and extent of AI services provided in the future will undoubtedly be the cost of providing such services.

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