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Genetic options to replace dehorning of beef cattle in Australia

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Abstract

Breeding polled cattle is a long-term solution to problems commonly associated with horned cattle. The current practice of dehorning is widely known to be like ‘treating the symptoms’, but ‘not eradicating the problem itself’. The present study reviewed the current state of knowledge on the genetic basis of polled inheritance in cattle. The polled / horned condition is controlled by a complex mode of inheritance through polled, scurs and African horn genes segregating independently, but interacting with each other to produce polled, scurred and horned animals. Molecular genetic studies have mapped the polled gene to a specific region on bovine chromosome 1, but the actual gene is still to be located. Scurs and African horn genes have not been studied thoroughly at a molecular level. With the current advances in molecular genetics and statistical methods, new research programmes should be undertaken to develop DNA tests for identifying homozygous/heterozygous animals for polled, scurs and African horn genes to assist in faster introgression of the polled condition into beef cattle populations. Results from a simple simulation program in various scenarios of low and high frequencies of polled gene and African horn gene have demonstrated that knowledge of DNA tests for both polled and African horn genes can significantly hasten the process of increasing the proportion of polled animals. The proportions of horned and polled cattle in various southern and northern Australian breeds are estimated based on the breed association records. Industry perceptions on the issue of breeding polled cattle and existing scientific evidence to counter such perceptions are presented. Various research and extension strategies to be undertaken for achieving the goal of replacing dehorning through genetic options are outlined.

Executive Summary

Dehorning is routinely practiced in beef cattle, as horns are an important cause of bruising, hide damage and other injuries, particularly in yards, feedlots and during transport. In addition to the economic losses through bruising estimated to be $22.5 million per year, horns also pose injury risk to cattle handlers, allow dominance behaviour in the yards and cause handling difficulties in crushes and during transport. Although it is advisable to dehorn at a young age, because of the mustering practices in some areas of Australia, dehorning may need to be carried out in older calves between 3.5 and 10 months age. Dehorning in older calves is labour intensive, causes more pain to the animal, takes longer to heal and is prone to secondary infection and mortality in some cases. In light of mounting animal welfare concerns about dehorning, breeding polled cattle is a non-invasive welfare friendly alternative. The present study provides a review of the current state of scientific knowledge regarding the polled gene while identifying impediments to breeding polled cattle. Research and extension strategies that need to be undertaken for increasing the proportion of polled animals in the national beef herd are also outlined.

1. *Numbers.*
   The proportions of horned, scurred and polled cattle in various major Australian beef cattle breeds are estimated based on the horns status records of the respective breed societies. The trends and proportions during recent years are used to group these breeds as predominantly horned (Brahman, Santa Gertrudis, Limousin), predominantly polled (Droughtmaster, Braford, Brangus, Simmental) and equal horned and polled (Hereford, Belmont Red, Charolais). In recent years, a trend towards an increase in polled cattle numbers has been observed in Hereford (combined records of Hereford and polled Hereford societies) and Limousin breeds. An estimate of the number of horned, scurred and polled cattle numbers in the major beef cattle breeds is obtained by extrapolating the horns status proportions in registered cattle to the national beef herd. Based on certain assumptions, it is estimated that there are 52% horned, 47% polled and 1% scurred cattle in the national beef herd. To have an impact on replacing the practice of dehorning at a national level, strategies need to be developed with the active involvement of big breed associations such as Hereford, Brahman, Santa Gertrudis etc.

2. *Inheritance.*
   It is widely accepted that the mode of inheritance of polled/horned/scurred condition in cattle is under the influence of the polled gene ('P' dominant to 'p'), African horn gene ('Ha' dominant to 'ha') and scurs (loose small horns) gene ('Sc' dominant to 'sc'). Scurs and African horn genes are sex-influenced. Scurs can only express in polled cattle and the African horn gene is epistatic (masks the expression by interacting) to polled gene. The African horn gene is expressed at a higher frequency in *Bos indicus* animals than *Bos taurus* animals.
   When 'P' is absent:
   - Males and females are horned irrespective of scurs and African horn genes.
   When 'P' is present:
   - 'Sc Sc' genotype causes scurs in both sexes, 'sc sc' causes no scurs and 'Sc sc' causes scurs in males only.
   - 'Ha Ha' causes horns in both sexes, 'ha ha' causes polled in both sexes and 'Ha ha' causes horns in males only.

3. *DNA tests.*
   The polled gene was mapped to bovine chromosome 1 and the scurs gene was mapped to bovine chromosome 19. However, the actual genes are not yet identified. MMI genomics is

marketing a DNA based diagnostic test for homozygous polled cattle applicable in some *Bos taurus* breeds. This test is not valid for scurs and is not useful in *Bos indicus* breeds. Inconclusive results are a possibility even in *Bos taurus* breeds. Major technical impediments to the development of DNA tests are ambiguity in phenotype determination (i.e. scurs and horns differentiation) and identification and development of resource populations for gene mapping studies.

4. *Introgression.*
   Polled gene introgression strategies into horned beef cattle populations can benefit from the use of marker information because of the ability to identify homozygous polled animals. Results from a simple simulation program in various scenarios of low and high frequencies of polled gene and African horn gene have demonstrated that knowledge of DNA tests for both polled and African horn genes can significantly hasten the process of increasing the proportion of polled animals.

5. *Industry perspective*.
   The beef industry is divided over the issue of breeding of polled animals and there are several concerns regarding the effect of polled gene on productivity. However, most scientific studies have demonstrated a lack of difference in growth, reproductive performance, mortality, carcass and behavioural traits between polled and horned animals in *Bos taurus* breeds. Such information is scanty in *Bos indicus* breeds. It is encouraging to note that there is a growing understanding of animal welfare concerns regarding dehorning in the industry and many breeders are interested in a decisive DNA test to identify homozygous polled bulls. The most significant case against the use of polled cattle in *Bos taurus* breeds is the evidence of some association between the polled gene and bull soundness issues such as premature spiral deviation of the penis (PSDP) and the preputial prolapse. This needs to be further investigated and if proven correct, remedial measures need to be identified.

6. *Research and extension strategies.*
   - Breeding strategies involve the identification of available homozygous polled bulls in major beef cattle breeds based on the progeny records and developing strategies to increase their numbers without compromising the achieved genetic gain. In predominantly horned breeds, specific polled bull breeding programmes need to be undertaken.
   - Developing DNA tests for the identification of homozygous polled and homozygous scurred animals is vital for the success of the breeding strategies to replace dehorning. Strategic alliances with international groups can lead to mutually beneficial outcomes at a faster pace. The competitive advantage for Australia is access to the pedigreed resource populations in *Bos indicus* animals crucial for mapping the African horn gene.
   - Performance comparisons of polled and horned animals in various beef cattle breeds are needed to counter the perceptions associated with poor performance of polled animals.
   - Extension strategies aimed at educating producers of the need for breeding polled animals should be undertaken while explaining the benefits of polled cattle and delivering the research results of performance comparison of polled and horned animals.

Because of the variability in the number of horned / polled animals among various breeds, different breeding strategies for different breeds need to be developed for the successful introgression of the polled gene into horned populations. The goal of replacing the practice of dehorning cannot be achieved overnight because of the complexity of inheritance and the huge numbers of horned cattle populations. Concerted efforts to develop and implement various research and extension strategies are needed to progress towards this goal in a phased manner. Advances in molecular genetic techniques play a significant role in addressing this problem by providing appropriate DNA tests.

Contents

1 Background

Horns in cattle are a major cause of bruising, hide damage and other injuries, particularly in yards, feedlots and during transport. Bruising in cattle is estimated to cost the Australian meat industry $22.5 million per year. The weight of bruised tissue trimmed from the carcasses of horned cattle is reported to be approximately twice that from hornless (dehorned or polled) cattle (Meischke *et al*., 1974). Also, cattle without horns have further advantages such as:

- Reduced injury risk for cattle handlers
- Quieter and better temperament
- Reduced dominance behaviour in the yards
- More animals can be accommodated in the same space during transport and in feedlots
- Easier to handle in crushes

Hence, dehorning is commonly used with horned breeds of cattle and the operation is covered by federal codes of practice and state legislation. The model code of practice for the welfare of cattle (Primary Industries Standing Committee, Commonwealth of Australia and each of its States and Territories, 2004) stipulates that dehorning should be conducted on calves at 6 months of age or less, or when they are first mustered. This should also be followed by regular inspections for the first 10 days to undertake any treatments, if needed.

In northern Australia, uncontrolled mating often occurs and hence calves can range in age between 3.5 and 10 months at the time of first muster (Bortulussi *et al.* 2005). Furthermore, if any calves are missed at the first muster, there can be a long delay before the next opportunity to dehorn them. Dehorning adult cattle is undesirable as it takes longer to heal and increases the risk of secondary infection. In some cases, this practice can result in short-term weight loss and mortality in rare cases. In some studies in northern Australia (Petherick, 2005), 3% mortality as a result of exsanguination after dehorning was reported. Warmer climates may also contribute to increased strain while healing. Behavioural responses of animals and welfare concerns of dehorning are well documented and dehorning under anaesthetic is advocated (Sylvester et al. 2004; Stafford and Mellar, 2005).

If horns are left untouched because of the problems of dehorning adult cattle, horned cattle become a hazard for others in the yards and during transport to slaughter or feedlot. Horned cattle are not preferred in feedlots at all. In Canada, feedlot managers bid less for intact horned animals at auction because of the risks in processing them (Goonewardene and Hand, 1991). They also reported a difference of 4.3% for average daily weight gain (over 106 days) between steers that were dehorned just before entering the feedlot and steers that were dehorned earlier or naturally polled. This amounted to a loss of 530 kg per 100 steers or the equivalent of one extra market weight steer.

In northern Australian conditions, Winks *et al*. (1977) observed that mature crossbred Brahman steers should not be dehorned because of the setbacks in weight gains. Anon (1974) reported that

Zebu or Zebu crossbred cattle bleed more than British breeds when dehorned as adults because of the thicker horn base.

Tipping is also practiced as an alternative to dehorning in some cattle operations. Tipping can vary in its severity from light tipping (2 cm cut off the end of the horn with no tenderness or bleeding) to heavy tipping (reducing the length of the horn to around 10 cm with bleeding and exposed cavities). This blunting of the horn is of doubtful value in preventing bruising (Anon, 1974; Winks *et al*. 1977). This is almost an unfinished job as the tipped horn continues to grow but with a blunt end. Improper tipping may end up having a horn which is as sharp as a normal horn and hence does not serve the purpose. Hence tipping may not be of much value given the time and effort put into it.

While Screw-worm fly is not currently found in mainland Australia, in the event of entry of Screw-worm fly from Papua New Guinea and coastal swamplands adjacent to Torres Strait (www.dpi.qld.gov.au/health/3958.html), where it currently inhabits, dehorning could pose a big threat to the beef industry as wounding is a prerequisite for Screw-worm fly strike. Production losses and death can result from this fly strike. Any measures that avoid such wounds would improve the capability of the Australian beef industry to deal with such possible threats. Breeding polled cattle is one such alternative.

It is clear that dehorning needs to be done at a very young age for it to have little impact on the later performance and to avoid mortalities. The best alternative to the invasive procedure of dehorning is breeding polled cattle, which provides a long-term solution to the problem of horns and addresses the welfare concerns of dehorning. Knowledge of the genetic control of polledness is incomplete and a definitive DNA test for polled alleles is not currently available. This report provides a review of the current state of world scientific knowledge of the genetics of the polled gene which identifies the technical and practical impediments (both real and perceived) to breeding polled cattle, and outlines strategies for increasing the proportion of polled animals in typical Australian herds.

2 Project Objectives

1. Obtain an estimate of the proportion of horned animals in the national beef herd in the major breeds in use.

2. Assess the state of current knowledge of the genes controlling expression of polledness in both *Bos taurus* and *Bos indicus* cattle.

3. Gauge industry concerns or reservations regarding the use of polled animals relative to horned animals.

4. Conduct a review of relevant literature to assess whether these concerns are supported by scientific data.

5. Evaluate options for introgression of polled genes into a horned herd using available selection criteria. This should include an estimate of the time required to approach 100% polled animals with typical breeds and herd structures in both northern and southern production systems; and an evaluation of the costs and benefits of alternative options, taking into account special management requirements.

6. Assess the potential impact of DNA markers on the rate of infusion of polled genes.

7. Determine the availability of commercial DNA tests for polled alleles and limitations of the current technology.

8. Investigate technical and commercial constraints to the further development of gene markers for beef cattle in Australia.

9. Identify knowledge gaps with, if appropriate, a prioritised listing of research and extension activities required to increase the proportion of polled cattle in the national herd.

3 Project Report

3.1 Proportion of horned and polled animals in major breeds of cattle

Australia is one of the world's most efficient producers of cattle and is the world's largest exporter of beef. As at June 2003, Australian national cattle numbers are reported to be 26.7 million (ABARE report, 2003) and 62% of total Australian beef production is sourced from Queensland (10.7 million) and NSW (5.8 million).

Breed-wise proportions (Appendix 6.4) indicate that Hereford is the major breed in Australia which is directly affected by horns status to the extent that two breed associations, the Hereford Society and Polled Hereford Society function as different entities. The Hereford Society registers cattle which are clear of polled ancestry for 6 generations. Some breeds such as Angus, Red Angus and Red Poll do not record the horn status routinely in their database as they consider their cattle to be 100% polled.

Estimating the number of horned, scurred and polled cattle in each of the major Australian beef cattle breeds is not an easy task and has to be based on certain assumptions. In the present study, horns status information from the historical breed society records is obtained which gives an indication of these numbers in the stud herds (Table 1). Table 1 summarises the historical breed society records of various major Australian breeds according to their horns status. It is apparent that horns status is not recorded (unknown) in a significantly higher proportion of cattle in some breeds.

Table 1. Summary of breed specific cattle numbers from historical breed society records according to horns status
Percentages (rounded to near decimal) are given in parentheses

	Horned	Scurred	Polled	Unknown	Total
Hereford and Polled	1204881	28392	1160271	28145	2421689
Hereford*	(49.8)	(1.2)	(47.9)	(1.2)	
Brahman	469287	708	67978	137596	675569
	(69.5)	(0.1)	(10.1)	(20.4)	
Santa Gertrudis	477181	3532	31628	6779	519120
	(91.9)	(0.7)	(6.1)	(1.3)	
Droughtmaster	55815	12992	142574	92	211473
	(26.4)	(6.1)	(67.4)	(0.0)	
Shorthorn	19575	238	4	372815	392632
	(5.0)	(0.1)	(0.0)	(95.0)	
Braford	0	3962	35549	117325	156836
	(0.0)	(2.5)	(22.7)	(74.8)	
Brangus	559	19	47385	2749	50712
	(1.1)	(0.0)	(93.4)	(5.4)	
Simmental	1243	1579	27781	307987	338590
	(0.4)	(0.5)	(8.2)	(91.0)	
Belmont Red	6399	703	5557	38020	50679
	(12.6)	(1.4)	(11.0)	(75.0)	
Limousin	103504	2042	28629	111521	245696
	(42.1)	(0.8)	(11.7)	(45.4)	
Charolais	42014	2335	31675	140117	216141
	(19.4)	(1.1)	(14.7)	(64.8)	

*Records of Hereford and Polled Hereford societies are pooled

- Shorthorn, Braford, Simmental and Belmont Red breeds have more than 75% of registered cattle with unknown horns status. Shorthorn has only 5% of the registered cattle recorded for horns status and all of them are horned. Hence, the Shorthorn breed is omitted from further summaries because of possible inaccuracies.

- Since 1993, Hereford Society records show an excessive number of cattle with 'unknown' horns status. The Hereford Society registers only horned cattle and hence these records are considered as 'horned' for preparing these summaries.

As cattle with unknown horns status are of little help in estimating number of horned, scurred and polled animals in various breeds, the indicative proportions according to horns status in various breeds are arrived at after deleting the animals with unknown horns status.

The basic assumption is that the proportions of horned, scurred and polled animals in the 'unknown' horns status cattle is similar to that of the 'known' horns status cattle (Table 2). This assumption may be incorrect in cases with a high percentage of 'unknowns' such as Braford.

Table 2. Summary of breed specific cattle numbers from historical breed society records according to horns status after deleting cattle with 'unknown' horns status
Percentages (rounded to near decimal) given in parentheses

	Horned	Scurred	Polled	Total
Hereford and Polled	1204881	28392	1160271	2393544
Hereford*	(50.3)	(1.2)	(48.5)	
Brahman	469287	708	67978	537973
	(87.2)	(0.1)	(12.6)	
Santa Gertrudis	477181	3532	31628	512341
	(93.1)	(0.7)	(6.2)	
Droughtmaster	55815	12992	142574	211381
	(26.4)	(6.1)	(67.4)	
Braford^	0	3962	35549	39511
	(0.0)	(10.0)	(90.0)	
Brangus	559	19	47385	47963
	(1.2)	(0.0)	(98.8)	
Simmental^	1243	1579	27781	30603
	(4.1)	(5.2)	(90.8)	
Belmont Red^	6399	703	5557	12659
	(50.5)	(5.6)	(43.9)	
Limousin	103504	2042	28629	134175
	(77.1)	(1.5)	(21.3)	
Charolais	42014	2335	31675	76024
	(55.3)	(3.1)	(41.7)	

*Records of Hereford and Polled Hereford societies are pooled
^More than 75% of registered cattle have unknown horns status

To be representative of the recent trends, these numbers are only taken from recent years i.e. since 1995, to estimate the percentages of horned, scurred and polled animals in various breeds (Table 3). However, it should be noted that in certain breeds (Braford, Simmental and Belmont Red), a high percentage of 'unknown' horn status animals exists in registered cattle. Hence the summaries and the groupings of these breeds need to be considered with caution.

Based on Table 3, beef cattle breeds can be grouped into 3 major groups:

Predominantly horned –	Brahman Santa Gertrudis Limousin
Predominantly Polled –	Droughtmaster Braford (high percentage of unknowns in the registered cattle) Brangus Simmental (high percentage of unknowns in the registered cattle)
Equal horned and polled -	Hereford (Hereford and Polled Hereford) Belmont Red (high percentage of unknowns in the registered cattle) Charolais

Table 3. Summary of breed specific cattle numbers from recent (since 1995) breed society records according to horns status after deleting cattle with unknown horns status Percentages (rounded to near decimal) given in parentheses

	Horned	Scurred	Polled	Total
Hereford / Polled	228212	3843	246909	478964
Hereford*^	(47.6)	(0.8)	(51.6)	
Brahman	182658	701	21649	205008
	(89.1)	(0.3)	(10.6)	
Santa Gertrudis	147886	1928	12873	162687
	(90.9)	(1.2)	(7.9)	
Droughtmaster	10329	5532	57984	73845
	(14.0)	(7.5)	(78.5)	
Braford^	0	749	6248	6997
	(0.0)	(10.7)	(89.3)	
Brangus	174	0	25280	25454
	(0.7)	(0.0)	(99.3)	
Simmental^	17	322	9912	10251
	(0.2)	(3.1)	(96.7)	
Belmont Red^	5094	652	5027	10773
	(47.3)	(6.1)	(46.7)	
Limousin	55861	1245	17760	74866
	(74.6)	(1.7)	(23.7)	
Charolais	21508	1314	18089	40911
	(52.6)	(3.2)	(44.2)	

*Records of Hereford and Polled Hereford societies are pooled
^More than 75% of registered cattle have unknown horns status

To estimate the number of cattle in various breeds within the national beef herd, the proportions of each of the breeds (Appendix 6.4) is multiplied by 26.7 million (ABARE report, 2003).

With an assumption that the same proportions of horns status as that of the stud herds exist in each of the breeds within the national beef herd, an estimate of horned, scurred and polled cattle numbers is obtained (Table 4) by multiplying the estimate of cattle numbers in each breed with the proportions of horns status based on recent breed society records (Table 3).

Combining these breed specific estimates with some assumed levels (based on *Bos taurus* or *Bos indicus* derived) in the rest of the breeds (not shown in the report), it is estimated that there are 52% horned, 47% polled and 1% scurred cattle in the national beef herd. This is an estimate given the available information, with a provision that the assumptions are correct.

Breed-wise, the number of horned, scurred and polled cattle registered during recent years (since 1995) are presented in Appendix 6.5. In each of these breeds, percentages (with known horns status) are plotted to study the trends in cattle numbers according to horns status. It is evident that in breeds such as Brahman, Santa Gertrudis, Droughtmaster and Brangus, proportions of horned and polled cattle have stabilised over recent years. In Hereford and Limousin, a trend towards increasing polled cattle registrations during recent years is apparent. Fluctuations in cattle numbers according to horns status are noticed in the Belmont Red breed. This could be because of the registration of various composite cattle in this breed society. In Charolais cattle, a slight trend towards an increase in horned cattle is noticed over recent years.

Table 4. Estimate of Horned, Scurred and Polled cattle in the major Australian beef breeds

Breeds	proportion[a]	numbers[b]	Horned[c]	Scurred[c]	Polled[c]
Hereford and Polled Hereford*	26.0	6942000	3307655	55700	3578645
Brahman	19.9	5313300	4734043	18168	561089
Santa Gertrudis	4.6	1228200	1116460	14555	97184
Droughtmaster	3.6	961200	134447	72007	754746
Braford^	1.4	373800	0	40014	333786
Brangus	1.1	293700	2008	0	291692
Simmental^	1.0	267000	443	8387	258170
Belmont Red^	0.8	213600	101001	12927	99672
Limousin	0.7	186900	139455	3108	44337
Charolais	0.6	160200	84221	5145	70833

[a]breed proportions as given in Appendix 6.4.
[b]estimated cattle numbers based on the proportions of the total 26.7 million Australian beef herd.
[c]estimated horned, scurred and polled cattle numbers given their proportions in stud herds in recent years (Table 3).
*records of Hereford and Polled Hereford societies are pooled
^More than 75% of registered cattle have unknown horns status

Based on the horns status in various breeds and the proportions of these breeds in the national beef herd, it is clear that strategies to replace dehorning in beef cattle need a different focus for various breeds. While it may be relatively easier and simpler to advocate the use of polled bulls in certain breeds (predominantly polled), concerted research and extension strategies need to be implemented for breeds with higher numbers of horned cattle. Moreover, for these strategies to have any impact on replacing the practice of dehorning, bigger breed societies such as the Hereford Society and the Brahman Society need to be actively involved.

3.2 Inheritance of horned / polled condition in cattle

The inheritance of horns was one of the earliest reported examples of Mendelian inheritance in cattle. However, as it turned out, it was one of the more complex inheritance patterns in cattle than initially assumed.

Absence of horns or polled condition supposedly originated because of a single gene mutation (from p to P) in many breeds of cattle. For example, the Polled Hereford breed was developed by one of two methods:

1. Crossbreeding of horned Herefords with other polled breeds and backcrossing to increase Hereford inheritance
2. By the continuous breeding of mutant polled animals

The study of inheritance of horns was focussed on the presence or absence of horns and scurs because of its obvious importance in cattle management. However, it should be noted that the variation in size, shape and orientation of horns could be under the influence of many genes like any other quantitative trait.

3.2.1 Single gene hypothesis

In 1902, Bateson and Sanders (reported in Shrode and Lush, 1947) were the first to report that the polled condition was dominant over the horned condition in cattle. This was further substantiated by various other studies (Spillman, 1906; Llyod-Jones and Evvard, 1916) supporting the single gene hypothesis of horn inheritance.

Gowen (1918) presented the first evidence to indicate that the simple dominance/recessive gene theory was not adequate to explain the horn inheritance. Occurrence of more horned males than females led to the hypothesis of sex-influenced inheritance. Thus the single gene theory was further extended to explain the inheritance as:

- Homozygous dominant (PP) – polled in both sexes
- Heterozygous (Pp) – horned in males and polled in females
- Homozygous recessive (pp) – horned in both sexes

This theory gained wide acceptance as the horns inheritance in major *Bos taurus* breeds generally followed this pattern. Watson (1921) interpreted from his study that the gene for polled was completely dominant in females, but for horns to be inhibited but not completely suppressed in heterozygous males to varying degrees among breeds. This was one of the first attempts to explain the scurs inheritance.

Smith (1927), among others, suggested the sex–influenced nature of horns and scurs inheritance in cattle. He suggested that there appeared to be factors modifying the normal mode of inheritance and provide evidence for the existence of the African horn gene in his study involving indigenous cattle of Africa. He also observed that castration of males did not modify the horns to any great extent, despite the sex differences in the inheritance of horns.

3.2.2 Multiple gene hypothesis

White and Ibsen (1936) were the first to formulate the most comprehensive and complex hypothesis explaining the mode of inheritance of horned / polled / scurred condition through four independently segregating genes:

P Completely dominant gene for polled condition and completely epistatic to horns (H) in both sexes. p – signifies the absence of P.

H Gene for horns. Always present in both sexes in homozygous state and epistatic to the gene for scurs (Sc). h – does not exist in domestic cattle.

However, Shrode and Lush (1947) stated that this hypothesised locus complicated the explanation needlessly. Hence this locus can be ignored and still the inheritance of horns can be explained.

Ha African horn gene epistatic to P in males; not certain in females. It is present in many breeds but at a low frequency in *Bos taurus* breeds and at a higher frequency in *Bos indicus* breeds.

Sc Gene for scurs. The expression of the gene is sex-influenced. The heterozygote (Sc sc) is scurred in males, but only homozygote (Sc Sc) is scurred in females.

This hypothesis generally stood the test of various other subsequent studies and was widely accepted with some minor variations.

Although, Williams and Williams (1952) supported White and Ibsen's (1936) theory of four pairs of alleles controlling the polled/horned/scurred phenotype, they suggested changing scurred to a recessive instead of a dominant gene. However, later studies (Long and Gregory, 1978) supported the earlier hypothesis of scurred being a sex-influenced dominant factor.

Long and Gregory (1978) summarised the inheritance of horned, scurred and polled condition in a study involving 830 progeny from various Angus (polled), Polled Hereford and Hereford sires. None of the progeny were dehorned and progeny were classified between 400 and 470 days of age for head condition and shape, presence of scurs, scur size and presence of bumps under hide.

They stated that -

- The single locus model with multiple alleles did not explain inheritance adequately.
- The inheritance model proposed by White and Ibsen (1936) of four separate loci was generally consistent with results obtained.
- Males heterozygous for scurs (Sc sc) must also be heterozygous for polled (P p) if scurs are to be expressed indicating "incomplete penetrance".
- Selection of cattle with a peaked poll should contribute to a reduction in the percentage of scurred animals produced.

Allele frequencies at polled, scurred and African horn loci differ greatly between breeds and populations within breeds, reflecting selection choices of the respective breeders.

3.2.3 Scurs

The definition of scurs has been the point of discussion for a long time with varying explanations for their differentiation from horns. Scurs grow in the same position on the frontal bone as horns and so the presence of horns masks the expression of scurs.

Initial studies varied in their classification of scurred and horned animals.

- Gowen (1918) observed that scurs are either loosely or firmly attached to the skull and the horns are big, obvious by their size.

- Cole (1924) classified scurs as always loosely attached and horns as always firmly attached.

- Dove (1935) studied the physiology of horn growth and emphasised that:

    - horns have the bony core which fuses to the skull.
    - scurs have a bony core at the distal end of the scur and at the same time have a bony deposit on the skull at the base of the scur.
        - The bony deposit at the base of the scur may extend upward only a short distance (loose scurs).
        - It may extend far enough to give complete rigidity, but without reaching the bony core at the distal end of the scur (rigid scurs). These rigid scurs are often mistaken as horns.

Dove (1935) for the first time stated that horn core was not an outgrowth of the skull as previously considered, but it was due to a separate centre of ossification originating in the tissues above the periosteum, fusing later to the skull.

Williams and Williams (1952) presented one of the most comprehensive reviews on the inheritance of horns in cattle. They described the horn phenotypes in Hereford cattle in their study as:

Horns – Horns are of varying length and shape from short curved horn to huge sweeping horns.

Tight Scur – Very short stub horn which is firmly attached to the frontal bone.

Loose scur – Same as tight scur except that it is smaller and attached to skin instead of the skull.

Round Poll – The skull between the horn loci is rounded and there appears to be a slight protuberance at the horn loci of most individuals.

Peaked Poll – The centre of the frontal eminence is peaked rather than rounded. This type of polled animal is much more reliable in producing completely polled animals than another phenotype.

Blackwell and Knox (1958) studied the inheritance of scurs in a herd of Aberdeen-Angus cattle. Their observations indicated that scurs are inherited as a sex-influenced trait with the male heterozygote (Sc sc) being scurred; but in the female only the homozygote (Sc Sc) is scurred.

Long and Gregory (1978) noted that the presence of scurs was not independent of skull shape, with scurs found in descending order on flat polls, rounded polls, peaked polls and extremely peaked polls (poll being the central prominence on the head). Many studies (Williams and Williams, 1952; Long and Gregory, 1978; Frisch *et al*. 1980) have reported unilateral occurrence of scurs i.e. animals which were scurred on one side and with polled or horned on the other. This indicated the complexity of the inheritance of scurs as well as the influence of non-genetic factors in the expression of horn-type.

According to Brenneman *et al*. (1996), examination of the severed horn revealed cavities extended from the frontal sinus into the horn core (Cornual diverticulum), further into the horn from approximately 2 cm to several centimeters depending on the length of the horn. Scurred animals possessed large protuberances at the location corresponding to the point of horn attachment. The scurs were filled with cartilaginous material much like that found at the corresponding point on the skull. Animals with scurs that felt attached to the skull showed a degree of fusion of cartilaginous tissues with a continuous distribution of ossification of the cartilaginous tissue to the point of attachment.

The complexity in the study of inheritance also lies in the fact that occasionally an animal classified as having scurs at the age of weaning (6 – 9 months) may develop them into horns at a later stage in life. In some cases, animals classified as polled at 6 months of age can grow small scurs at a later date. This mode of inheritance and the expression of phenotype influenced by the age of the animal complicate the study of inheritance based on phenotypes alone. This is why a definitive DNA test for differentiating scurred, horned and polled animals is needed, so that they can be identified early in life to make appropriate breeding decisions.

3.2.4 African Horn gene

The African horn gene, as the name suggests, is rare in British breeds but supposedly at a higher frequency in Zebu cattle. African horn gene is believed to be segregating independently but with an epistatic effect on the 'polled' locus and is sex-influenced in its inheritance i.e. heterozygotes in males are horned and in females are polled. This assumption is based on the occurrence of a higher frequency of horned offspring from crosses between purebred polled *Bos taurus* breeds and horned *Bos indicus* breeds and the occurrence of polled offspring from horned parents.

However, Georges et al. (1993) cautioned that scurred and African horn gene could also be different alleles at the same locus.

It should be easier to eliminate 'Ha' than 'p' in males because if a bull is polled, it does not carry the African horn gene (Table 5). However, identifying female carriers of 'Ha' is difficult because a female has to have two 'Ha' genes in order to be horned. Hence, it is difficult to control 'Ha' alleles in breeds where they are at higher frequencies. One possibility is to select against all females with horns and all females that produce a horned calf when bred to a proven homozygous polled bull. This would lead to lot of progeny testing for polled condition and lot of culling at breeding age which is not practicable.

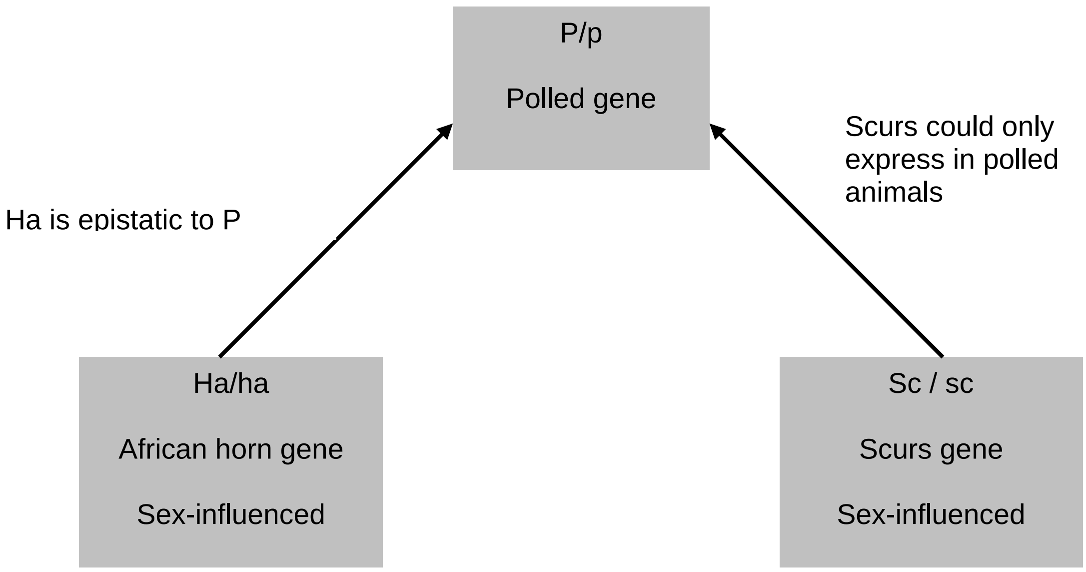
Hence, DNA test/s that could potentially identify -

a) homozygous / heterozygous polled
b) homozygous / heterozygous scurred
c) homozygous / heterozygous African horn

would hasten the process of transforming the horned population into a polled population.

3.2.5 Widely accepted pattern of horns inheritance

Several researchers working on the discovery of genetic markers closely linked to the polled gene have followed the hypothesised theory of polled/horned/scurred inheritance. The three gene theory (ignoring the H gene proposed by White and Ibsen, 1936) can be summarised as below and is widely accepted to explain the horn/poll inheritance in cattle.



This mode of inheritance basically assumed the following genotypes for the phenotypes seen from the crosses (Table 5).

Table 5. Inheritance of scurred and African horn genes in beef cattle (Georges *et al*. 1993)

Genotype	Males	Females
	Inheritance of the scurred phenotype	
P/- Sc/Sc	Scurred	Scurred
P/- Sc/sc	Scurred[a]	Polled
P/- sc/sc	Polled	Polled
p/p -/-	Horned	Horned
	Epistatic effect of the African horn gene on the polled locus	
P/- Ha/Ha	Horned	Horned
P/- Ha/ha	Horned	Polled
P/- ha/ha	Polled	Polled
p/p -/-	Horned	Horned

[a]Sc/sc males express the scurred phenotype only when heterozygous P/p according to Long and Gregory (1978).

3.3 Molecular genetic studies to identify 'polled' gene in cattle

Because of the complexity surrounding the mode of inheritance (as explained in the previous section) through three loci – polled, scurred and African horn and the sex-influenced nature of inheritance (of scurs and African horn genes) coupled with epistatic effects, horns status phenotype is not a suitable determinant for making breeding decisions to propagate polledness in cattle. It is crucial to know the homozygous/heterozygous state at these loci to effectively reduce the proportion of horn alleles in the breeding population while keeping a tab on the masked phenotype of 'scurs' (scurs genes do not express in horned animals even in the dominant homozygous state). Propagation of the polled gene in purebred herds has been hampered by this inability to distinguish between heterozygous and homozygous polled bulls. Molecular genetic approaches play a significant role in addressing this problem.

Availability of highly polymorphic microsatellite markers in the late 1980s led to studies identifying linked markers with the polled locus. These genetic markers, if available, could be used for implementing marker assisted selection strategies to increase the polled gene in breeding populations, even without knowing the actual location of the gene.

Georges *et al*. (1993), for the first time, demonstrated a genetic linkage between the polled locus and two microsatellite markers in *Bos taurus* cattle and assigned them to bovine chromosome 1. At a molecular level, this study confirmed the existence of a 'polled' locus and its hypothesised inheritance pattern. The genetic markers linked to a 'polled' gene in this study were relatively far from the actual location of the polled gene and hence, not directly useful in breeding programmes. But they laid the foundation for the search for closer markers to effectively trace the segregation of the polled gene.

Schmutz *et al*. (1995) also mapped the polled locus close to the centromere of bovine chromosome 1 in five Charolais cattle families known to segregate for both horned and polled. Karyotyping studies on these sire families, which were carriers of Robertsonian translocation 1:29 indicated that the polled locus was very tightly linked with the centromere of the chromosome in their study.

Brenneman *et al*. (1996) conducted an elaborate study to map the polled locus in the progeny of a *Bos indicus* (Brahman) X *Bos taurus* (Angus) cross. This is the only known study involving the use of Brahman cattle for gene mapping studies. Progeny were scored for polled, scurred and horned phenotypes at one year of age and again following skull dissection at slaughter at 20 months of age. While Georges *et al*. (1993) were unable to identify the position of the polled locus relative to the marker pair, Brenneman *et al*. (1996) mapped the polled locus proximal to the centromere and 4.9 cM from a microsatellite marker.

However, they listed the following limitations that affect the efficiency of marker assisted selection for polledness –

- Ambiguous phenotype determination - difficulties in discriminating between scurred and horned phenotypes as there appeared to be a continuum in scur/horn size and their attachment to the skull
- Potential linkage equilibrium among populations
- Map heterogeneity for gene order among populations

They also indicated that bracketing markers would be essential for refining the model of inheritance of the horned, scurred and polled phenotypes and for effective marker assisted selection. In the search for closely linked markers for the polled locus, Harlizius *et al*. (1997) also demonstrated a genetic linkage between a set of new microsatellite markers located on bovine chromosome 1 and the polled locus in European Simmental and Austrian Pinzgauer cattle. However, they could not order the polled locus relative to markers owing to low number of recombinants in the available families.

In sheep, the major allele at the horn locus controlling horn development was mapped to sheep chromosome 10 (Montegomery *et al*. 1996), the cattle homolog being chromosome 12. Though it was originally assumed that the candidate region for the horned locus in sheep was chromosome 1 because it showed conserved synteny with cattle chromosome 1 (where the polled locus was located), Montegomery et al. (1996) mapped it to chromosome 10. As this gene in sheep is sex-influenced just like the African horn gene in cattle, they postulated that the African horn locus may be located on bovine chromosome 12 in cattle. However, this needs to be tested and no verification of this hypothesis has been carried out.

Asai *et al*. (2004) have mapped the scurs locus to cattle chromosome 19 in 3 full-sib families from the Canadian beef cattle reference herd developed from *Bos taurus* cattle for gene mapping studies. They also found that scurs were not sex-linked based on the information from markers tested on the X chromosome, even though the phenotype appeared only in male offspring in their studies.

More recently, Drögemüller *et al.* (2005) conducted a fine mapping study in 30 two-generation half-sib families of six different German cattle breeds. They could able to narrow the critical region for the bovine polled locus to a 1 – Mb segment with a centromeric boundary at RP42-218j17_MS1 and a telomeric boundary at BM6438 in these *Bos taurus* breeds. They also stated that the first evidence of informative flanking markers should help in predicting polled genotypes with a higher degree of accuracy within families.

3.3.1 Commercial DNA test for 'Polled' gene

MMI Genomics Inc. have advertised the first DNA based diagnostic test (TRU-POLLED) for homozygous polled cattle recently. 'Tru-Polled' is claimed to have been validated for use with *Bos taurus* breeds namely Charolais, Gelbveih, Hereford, Limousin, Salers and Simmental cattle. More information can be obtained on this test from http://www.metamorphixinc.com/faqtrupolled.html.

The cost of the test is US$110 per animal and the results of the test are reported in one of the four categories.

1. Homozygous polled – two copies of the polled gene
2. Heterozygous polled – one copy of the polled gene and one copy of the horned gene
3. Horned – no copies of the polled gene, two copies of the horned gene
4. Inconclusive – test cannot determine if the animal has copies of either horned gene or the polled gene.

They clarify that breeders can expect inconclusive results in 10 to 15% of the animals tested and currently they are not charging for the inconclusive results.

There are some limitations –

1. This test is not capable of detecting presence or absence of scurs.
2. This test may not be valid in *Bos indicus* animals or even in *Bos taurus* populations where the 'African horn' gene is at a higher frequency.
3. Inconclusive results are quite possible.

3.3.2 Technical and commercial constraints for developing gene markers

With the current knowledge of the mode of inheritance and the phenotypic expression of the trait, some of the constraints that may affect further development of genetic markers for polledness in beef cattle are given below.

Ambiguity in phenotype determination - One of the significant technical impediments as reported by Brenneman *et al*. (1996) for mapping studies is the wrong identification of phenotypes. As reported by them, there is a continuum in scur and horn size and their attachment to the skull. A horned animal can never show its genetic scurs status as the horn phenotype masks the scurs because of their same location. This ambiguity may potentially rule out the use of existing resource populations for genome scanning purposes to a certain extent. There is a need for developing specific resource populations for accurate identification of the phenotype in targeted *Bos taurus* and *Bos indicus* breeds. Breed association records will still be useful for identification of sire families (where these genes are segregating) and further validation studies.

Identification / development of resource families for gene marker studies - The most important part of developing genetic markers is the identification / development of proper resource families where these genes are segregating. This may involve producing more progeny from identified sires such that various phenotypes are generated.

Commercial constraints – The need for generating these resource populations and subsequent genome scans pose a considerable commercial constraint. Strategic alliances among various international groups will be of great help and potentially reduces the duplication of work. From an Australian perspective, such an investment would open up opportunities to take international leadership in studying polled inheritance in *Bos indicus* breeds, focussing on the African horn gene. This could have a huge international impact and provide marketing opportunities across Central and South America and Africa.

Abundance of genetic markers - Availability of polymorphic genetic markers in the particular region of the chromosome is another requirement for such a gene discovery study. This may not be a big issue anymore. With the completion of the sequencing of the bovine genome, we currently have access to literally thousands of markers (SNPs) across the whole genome which will be extremely useful for the mapping studies.

Publicly available information on the probable location of the polled gene and knowledge gained from the recent completion of bovine genome sequencing has enabled a situation to positionally clone the genes controlling the inheritance of polled, scurred and horned phenotypes in cattle. In the immediate future, it may be possible to identify tightly linked markers to polled, scurred and African horn genes, thereby assisting in the progress that can be made through marker assisted introgression.

Strategic alliances with international groups already working in this area could hasten this process through sharing the existing knowledge on mapping of the polled gene in *Bos taurus* animals and more importantly making headway towards mapping the African horn gene, which has greater implications for Australia's beef industry because of the evidence of its presence in Brahman and Brahman derived cattle.

3.4 Introgression of the polled gene

In beef cattle, because of longer generation intervals and lower reproductive rates, introgression is only viable for genes of large effect and genes affecting traits such as presence or absence of horns. Introgression of the polled gene into beef cattle breeds can be attempted by continuously breeding polled bulls with horned cows and selecting for polled cows and bulls for breeding in later generations. Though it sounds simple and achievable in principle, the complexity of inheritance and the lack of sufficient numbers of genetically superior polled bulls in certain breeds pose problems for its successful implementation.

Polled gene introgression strategies can benefit from the use of marker information (marker assisted introgression) because of the increased accuracy in the identification of genetic status of the gene (i.e. homozygous vs. heterozygous). These markers can be direct markers or linked markers. Direct markers are the actual genes that code for the phenotype and linked markers are those that are closely linked with the genes that code for the phenotype. Introgression strategies are also affected by the frequency of the desired gene in the population.

3.4.1 Sex-wise horns status percentages at various allele frequencies

The sex-influenced nature of the scurs gene and the epistatic effect of the African horn gene influences phenotypic expression of the polled gene. The variation in the percentage of horned/scurred/polled phenotypes at various favourable allele frequencies of polled (P – polled allele), scurs (sc – recessive scurs allele) and African horn (ha – recessive African horn allele) genes is shown in Table 6.

Table 6. Percentages of horns status phenotypes at various allele frequencies of Polled, Scurs and African horn genes
Polled gene – 'P' is favourable allele and 'p' is unfavourable allele; Scurs gene – 'Sc' is unfavourable allele and 'sc' is favourable allele; African horn gene – 'Ha' is unfavourable allele and 'ha' is favourable allele

	Males (%)	**Females (%)**
Very High favourable allele frequencies (P=0.9; ha=0.9; sc=0.9)		
Horned	19.8	2.0
Scurred	15.2	1.0
Polled	65.0	97.0
High favourable allele frequencies (P=0.7; ha=0.7; sc=0.7)		
Horned	55.4	17.2
Scurred	22.7	7.4
Polled	21.9	75.4
Moderate favourable allele frequencies (P=0.5; ha=0.5; sc=0.5)		
Horned	81.2	43.7
Scurred	14.1	14.1
Polled	4.7	42.2
Low favourable allele frequencies (P=0.3; ha=0.3; sc=0.3)		
Horned	95.4	74.0
Scurred	4.2	12.7
Polled	0.4	13.3
Very Low favourable allele frequencies (P=0.1; ha=0.1; sc=0.1)		
Horned	99.8	96.4
Scurred	0.2	2.9
Polled	0.0	0.7

It is clear that even at very high frequencies (90%) of the favourable alleles, 35% of males are either horned or scurred. At the intermediate (0.5) allele frequencies of polled, scurs and African horn genes, more than 95% of males and around 60% of females are either horned or scurred. This highlights the potential problems associated with breeding polled animals in populations with relatively low to moderate gene frequencies of the favourable alleles. At low (0.3) and very low (0.1) frequencies of favourable alleles, males and females are predominantly horned or scurred.

Another complicating factor is that at least 50% of the polled males are heterozygous at the polled gene and at least 50% polled females are heterozygous at the polled, scurs and African horn genes. This poses problems relating to selection of breeders. The availability of DNA tests enables the identification of homozygous polled animals for future breeding and thus, effective introgression of polled genes into the population.

3.4.2 Simulation study

Given the complexity of inheritance and the phenotypic expression of horns status at various allele frequencies explained above, a simple simulation is conducted to compare various scenarios arising out of four combinations of low (0.3) and high (0.7) favourable allele frequencies at polled and African horn loci. These scenarios are compared to estimate the number of years taken to achieve 100% polled animals with or without the availability of DNA tests. This simulation is conducted under the following set of assumptions and conditions:

- Each year 1000 cows are joined to 25 bulls. Initially, 10 years of breeding is conducted to stabilise gene frequencies without any selection for polledness. Selection for polled breeders is implemented from year 12 in the simulation.
- Selection of breeders (from year 12) is based on polled condition only, ignoring the rest of the traits (unrealistic under practical conditions). Each year, both bulls and cows are selected for polledness and if polled cows are less than 1000, then horned cows are included for breeding.
- Bulls are used for 2 years and cows have their first calf at 2 years and are kept in the herd up to 7 years.
- Replacement cows and bulls come from the same herd.
- Horned / polled condition is under the influence of polled gene (P/p) and African horn gene (Ha/ha). Scurs are ignored.
- Best case scenario of gene test is assumed (direct marker test i.e. not a linked marker test).
- Four scenarios based on allele frequencies:

Scenarios	P (favourable allele of polled gene)	ha (favourable allele of African horn gene)
1. Low ‘P’ and low ‘ha’	0.3	0.3
2. Low ‘P’ and high ‘ha’	0.3	0.7
3. High ‘P’ and low ‘ha’	0.7	0.3
4. High ‘P’ and high ‘ha’	0.7	0.7

Scenario 1 with lower allele frequency of polled gene and lower frequency of favourable allele of African horn gene is comparable to the *Bos indicus* breeds and Scenario 4 with higher frequencies of favourable alleles at polled and African horn loci is comparable to the *Bos taurus* breeds in Australia.

- In each of the above mentioned allele frequency combinations; selection of breeders is based on:
  - no DNA test (based on polled phenotype)
  - polled gene test
  - African horn gene test
  - both tests

Number of years to achieve 100% polled animals in the simulated population (average from 50 replications) varied substantially in various above mentioned scenarios (Table 7). Year-wise change of polled animal frequency under various scenarios is presented in Figures 1 to 4.

Table 7. Estimated number of years to achieve 100% polled animals at various frequencies of favourable alleles

Scenarios	No DNA test	Polled gene test	African horn gene test	Both tests
1. Low ‘P’ and low ‘ha’	39 years	25 years	38years	8 years
2. Low ‘P’ and high ‘ha’	33 years	18 years	33 years	6 years
3. High ‘P’ and low ‘ha’	30 years	23 years	30 years	6 years
4. High ‘P’ and High ‘ha’	30 years	18 years	28 years	4 years

The advantage of marker assisted introgression is obvious from Table 7. While the availability of the African horn gene test alone does not hasten the introgression process, it is evident that knowledge of both tests gives substantial advantage in achieving the objective of 100% polled animals in all the scenarios.

Especially in northern Australian beef herds and in breeds where favourable alleles (P and ha) are at a lower frequency, it is crucial to have information on both gene tests to effectively introgress the polled gene. The problem in these breeds is the unavailability of polled bulls and specific polled bull breeding programmes can be implemented easily, if DNA tests are available. Information on any one of the genes is not effective enough because of the complex nature of inheritance. However, it is possible that in some of the *Bos taurus* breeds, the unfavourable allele of the African horn gene may be at very low frequencies or even fixed for its favourable allele. In such cases, a test for the polled gene may be effective for achieving desirable results.

The importance of DNA tests increases under more realistic scenarios such as, lower selection pressure on the polled gene, because of the emphasis on other economic traits. Under practical conditions, these tests will be useful in deciding selective use of genetically proven bulls i.e. two polled bulls of relatively similar EBVs for important production traits can be compared for their genotype at the polled, scurred and African horn loci before making breeding decisions.

3.4.3 Commercialisation

Although a proper cost-benefit analysis is not attempted in this study for evaluating the net benefit of DNA tests, given the importance of replacing the practice of dehorning and the ineffectiveness of simple breeding strategies in introgressing polled genes in major Australian breeds, investment in the development of DNA tests is an economically wise decision. There is also a potential international market for such tests. Strategic alliances in the further development of polled gene tests while concentrating on the development of tests for African horn gene can give us a commercial advantage. Tests for the African horn gene and scurs gene will have demand in Central and South America and Africa. Such technology can be commercialized by licensing to a suitable biotechnology company that markets the DNA tests. The existing commercialisation channels in the marketing of genetic markers for marbling and tenderness could also be utilised for greater market access.

Fig 1. Number of years to achieve 100% polled animals (1.0 frequency) in a breeding population with low 'P' and low 'ha' frequencies
'P' and 'ha' are the favourable alleles of polled and African horn genes respectively; selection for polled starts from year 12

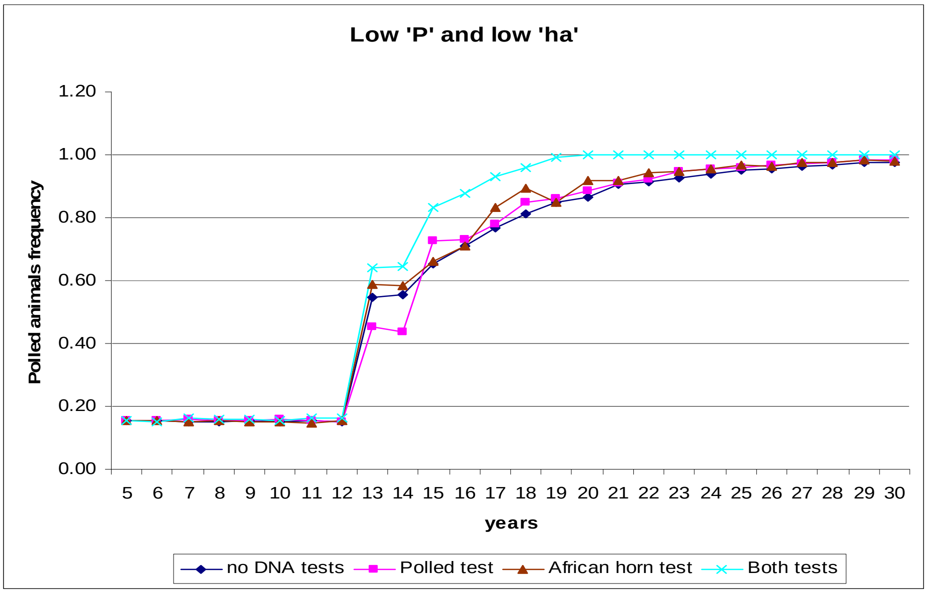


Fig 2. Number of years to achieve 100% polled animals (1.0 frequency) in a breeding population with low 'P' and high 'ha' frequencies
'P' and 'ha' are the favourable alleles of polled and African horn genes respectively; selection for polled starts from year 12

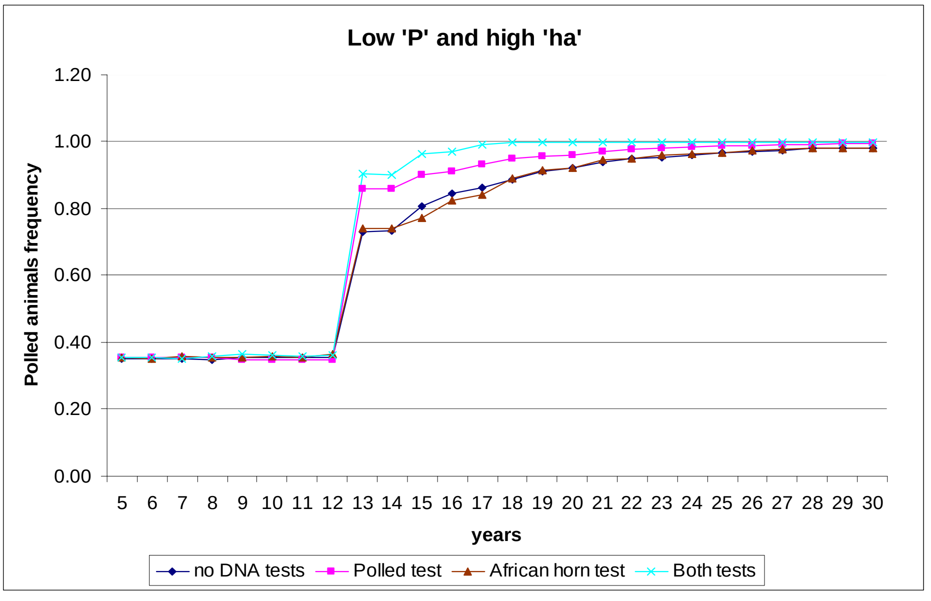


Fig 3. Number of years to achieve 100% polled animals (1.0 frequency) in a breeding population with high 'P' and low 'ha' frequencies
'P' and 'ha' are the favourable alleles of polled and African horn genes respectively; selection for polled starts from year 12

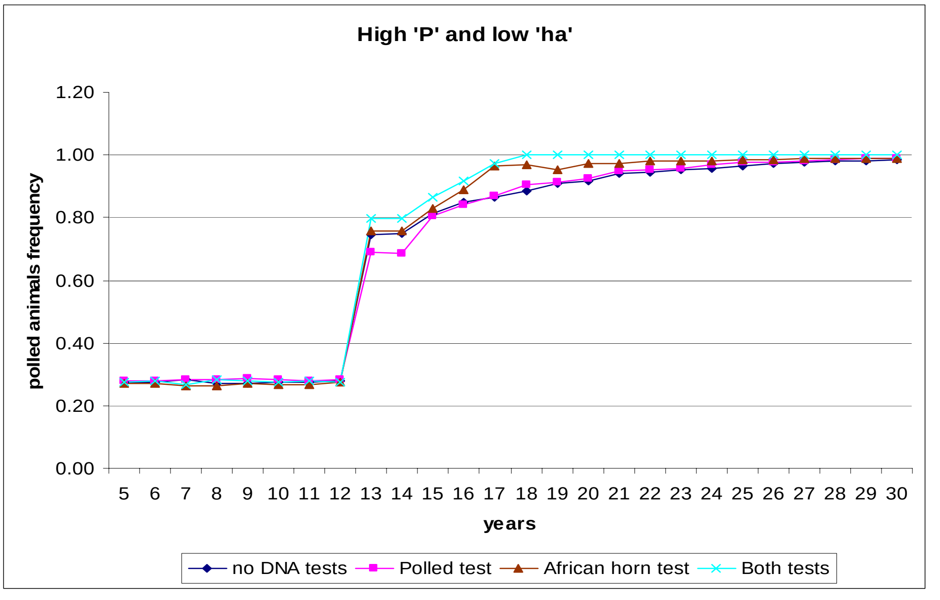
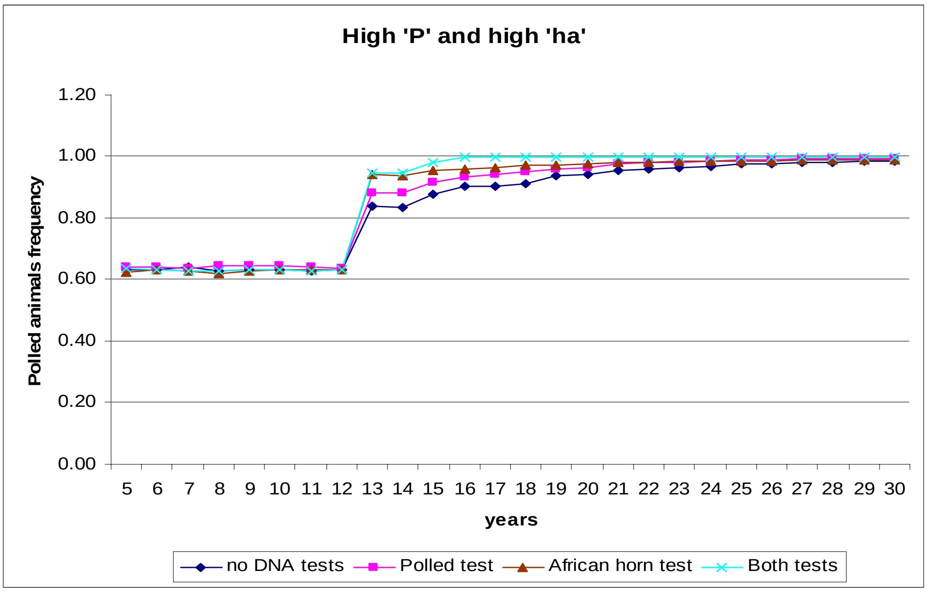


Fig 4. Number of years to achieve 100% polled animals (1.0 frequency) in a breeding population with high 'P' and high 'ha' frequencies
'P' and 'ha' are the favourable alleles of polled and African horn genes respectively; selection for polled starts from year 12



3.5 Industry perspective of polled / horned cattle

The beef cattle industry is divided over the issue of polled/horned cattle in Australia, evidenced by the existence of two breed societies for the same breed namely Polled Hereford and Hereford. There is a belief in some sections of the industry that horned cattle are more productive than polled cattle. This perception is slowly changing and has been, to a certain extent, aided by animal welfare concerns associated with dehorning. Increasing awareness among cattle breeders about the need for breeding polled cattle is evident and the increased use of polled Angus is one such example. Largely individual preferences are directing this issue rather than any strong evidence based convictions. However, some stud breeders suggest that they could sell more polled bulls than horned bulls and that, all being equal; polled bulls are more valuable than horned bulls, reflecting the changing mood of the industry (Wayne Upton, personal communication).

3.5.1 Industry concerns regarding breeding polled animals

Industry concerns with breeding polled animals as stated during the course of this discussion are listed below. It should be noted that these are perceptions of various people in the industry (refer Appendix 6.2).

1. Horned animals are more productive than polled animals.
2. Horned animals have better bone, fitness of body and better muscling.
3. Polled cattle are more temperamental.
4. Polled gene is associated with the condition of premature spiral deviation of the penis or cork screw penis in *Bos taurus* breeds.
5. Serving capacity of horned bulls greater than polled bulls.
6. Preputial prolapse and sheath problems are more common in polled bulls.
7. In tropical cattle, horns are associated with resistance attributes of cattle – i.e. polled cattle don't hold up as well as horned cattle during tough times.
8. Horned animals can scare dingos away thereby protecting their young calves from attacks from predators. For this reason, at least some of the cattle are left with horns.
9. In Brahman and Brahman derived cattle, there is a perception that polled cattle are less fertile.
10. Genetic progress may not be possible without horned animals, especially in breeds such as Brahmans where horned animals are in higher numbers.
11. In Brahmans, there are not enough polled bulls to breed and highly ranked horned bulls are available.

There is also a perception in the industry that because of the existing numbers it is not feasible to "breed out" horned cattle in the immediate future.

On the other hand, there is also a growing understanding of animal welfare concerns involving dehorning. Thus, industry has taken a proactive lead in funding this review to better understand the genetics of horns and the ways to address this problem. There is increasing opinion that over the next few years both Hereford breed societies (Hereford and Polled Hereford) should merge and increased awareness of the need for breeding polled cattle is also evident. There is a strong desire to have a DNA test to identify the polled gene to avoid the frustration of designing a breeding programme without actually knowing whether bulls are homozygous polled or heterozygous polled. The need for such tests is also influenced by the devaluation of bulls because of scurs in polled breeds.

3.5.2 Scientific evidence against industry concerns

Contrary to some perceptions that horned cattle are better performers than polled cattle, scientific evidence suggests that there are no significant differences between polled and horned animals in any of the production and reproduction traits as evidenced in many studies:

- No significant differences in live weight in Shorthorns (Marlowe *et al*., 1962) and in mortality rates in Herefords (Longland *et al*., 1976 as cited in Frisch *et al.* 1980) were reported between polled and horned cattle.
- Although some earlier studies (Wythes *et al*. 1976) reported a higher incidence of dystocia in polled Herefords than in horned Herefords, this is based on survey data without proper adjustment of management effects in the analysis.
- In buffaloes (Mason, 1974) and goats (Hancock and Louca, 1975), reproductive disturbances associated with polledness have been reported. In the Damascus breed of goats, Hancock and Louca (1975) observed a relationship between polledness and intersexuality with polled x polled matings producing a certain proportion of sterile males and females. In Saanen goats (Soller *et al*. 1969) reproductive tract abnormalities have been conclusively linked to polledness which appears in the progeny from polled x polled matings. However, polled genes are not associated with any abnormal sexual development in cattle and no such reports exist in the literature.
- Frisch *et al*. (1980) found no significant differences between horned and polled cattle in live weight, fertility or mortality rates indicating that polledness had no detrimental effect on production in tropically adapted genotypes.
- Expression of horns and scurs was associated with maleness, presumably through the action of male sex hormones, but Frisch *et al*. (1980) found that horned males were not more fertile than polled males. They also reported that polledness was not related to cryptorchidism (one or both testes undescended) in cattle.
- In Canada, Stookey and Goonewardene (1996) and Goonewardene *et al*. (1999b) reported no differences in growth and carcass traits between polled and horned Charolais, Hereford and composite *Bos taurus* bulls.
- Goonewardene *et al*. (1999a) reported no differences between horned and polled cattle in three beef synthetic lines (*Bos taurus*) for various growth and reproductive traits such as pregnancy, calving and weaning rates, calf birth and weaning weights, calf preweaning average daily gains, dystocia score, cow weight and cow condition scores.
- Behavioural responses to various handling and restraints in dehorned and polled calves did not show any significant differences (Goonewardene *et al*. 1999c). This counters the argument that genetically polled cattle are more temperamental because of the feeling of insecurity.

Hence, breeding for polledness is advocated as a simple, welfare-friendly and non-invasive method of eliminating horns from farmed cattle populations.

3.5.3 Polled gene and Bull soundness issues

The association of the polled gene with bull soundness issues is by far the most significant case against use of polled cattle in *Bos taurus* breeds. Reports in *Bos indicus* cattle are scanty, but again this may be due to fewer polled cattle.

Premature spiral deviation of the penis (PSDP) or corkscrew penis in cattle was reported in bulls in North America, South Africa, Britain, Uruguay and New Zealand (See Blockey and Taylor, 1984 for cited references). Premature spiral deviation occurs when the erect free end of the penis of an affected bull spirals to the right hand side in an anticlockwise direction. The effective width of the penis doubles, thus preventing intromission. PSDP develops due to lack of strength in the dorsal apical ligament of the penis, which is unique to bovine species with a function to keep the free end of the penis straight until intromission is achieved. Comparison of genitalia recovered from abattoirs show the differences in the size of the dorsal ligament in polled and horned bulls.

Blockey and Taylor (1984) reported a higher prevalence of PSDP in polled bulls (16%) compared to horned bulls (1%) in their study on 1083 British breed beef bulls. Common ancestry was found between affected bulls providing evidence of an inherited defect and its occurrence increased with the advancement of age as a result of repeated tension on the penile tissues. Unfortunately due to this, the majority of cases of PSDP could not be recognised in unmated 2-year-old stud bulls. Hence, a serving capacity test is the major diagnostic method for observing any preliminary signs of PSDP. They also concluded that bulls with moderate to severe spiral deviation of the penis had reduced fertility and remain permanently affected.

However, as this defect occurs at lower proportions and as it is genetically inherited it can be eliminated from the breeding population through planned culling of bulls.

In a study involving a limited sample of Santa Gertrudis bulls, Holroyd *et al*. (2005) concluded that there was no evidence that the polled bulls had poorer preputial muscle development than horned bulls or that they everted their prepuces (Preputial prolapse) further than horned bulls. This was contrary to certain reports from *Bos taurus* bulls wherein polled bulls were susceptible to preputial prolapse because of the heritable weakness of the retractor and protractor muscles of the prepuce (Rice 1987; Bruner and Van Camp 1992). However, only 5% of the total bulls culled were due to specific problems such as reproductive problems, conformation or temperament problems. Of these, the visible reproductive problems were mainly due to damaged penises and prepuces. Some of this damage can be attributed to preputial prolapse. This confirmed that incidence of this problem in these bulls was minimal.

In another sub-project, Holroyd *et al*. (2005) also conducted anatomical studies on 8 polled and 15 horned Santa Gertrudis bulls with chronic preputial prolapse and observed that polledness was significantly related to a deficiency in the size and development of the preputial retractor muscle. However, obvious reasons for preputial prolapse in horned bulls could not be found.

3.6 Research and Extension strategies

Initially, dehorning was thought to be a simple solution for the problems associated with horns in cattle and hence most of the research was centred on developing methods of dehorning. It became clear that dehorning is like ‘treating the symptoms’, but ‘not eradicating the problem itself’. The importance of ‘breeding out’ horns from cattle populations has grown considerably due to animal welfare concerns. Simultaneous research and extension strategies need to be undertaken to achieve significant advances in replacing the practice of dehorning through breeding of polled animals in various breeds. Achieving this objective of breeding polled animals is more difficult in certain breeds (e.g. Brahman) than others because of the number of horned animals and the complex mode of inheritance.

3.6.1 Research strategies

The complexity of inheritance of the polled gene emphasises the need for an accurate DNA test to identify homozygous polled, heterozygous polled and horned animals. Stud breeders would value such a test to decisively introgress polled gene into the breeding population without any surprises. However, efforts to increase polled animals in the national beef herd need not wait for ‘DNA’ tests. Instead, research and extension efforts need to be integrated to deliver practical breeding strategies, while educating producers of the need for breeding polled animals.

Some of the myths surrounding the performance of polled cattle can be scientifically tested and publicised to encourage producers to accept polled cattle. This is of primary importance in *Bos indicus* cattle as there is not enough scientific information available comparing polled and horned animals in a wide range of traits.

Research strategies that need to be carried out are:

1. *Breeding* – Inventory of the available polled bulls in the major Australian beef breeds and evaluating the strategies to increase their numbers without compromising the achieved genetic gain.

    a. In breeds which are predominantly polled (section 3.1), homozygous polled bulls can be identified based on the existing progeny information from breed association records and developing strategies to increase polled bull numbers for those breeds without significantly increasing inbreeding levels or compromising the genetic progress.

    b. In breeds which are predominantly horned (section 3.1), the previous strategy can run into problems because of low numbers of polled bulls and complex inheritance patterns. Specific polled bull breeding programmes need to be developed to increase the number of polled bulls available. This strategy would benefit from the availability of DNA tests.

    c. Where possible, crossbreeding can be advocated as a breeding strategy to increase the proportion of polled animals. While this strategy may not be suitable in purebred cattle, it has good potential to increase polled cattle numbers in crossbred herds while increasing the performance attributes through heterosis.

2. *Molecular Genetics* - Developing DNA tests for the identification of homozygous polled and homozygous scurred animals is vital for the success of the above mentioned breeding strategies and hastens the process of introgressing the polled gene into the major Australian breeds. Strategic alliances with international groups working in this area could lead to mutually beneficial outcomes at a faster pace.

    a. The competitive advantage for Australia is the huge pedigreed resource populations of *Bos indicus* animals, where the ‘polled’ gene is segregating as evidenced by the polled Brahmans (section 6.5). While validating and developing the available tests in *Bos taurus* animals, collaborative research efforts can concentrate on developing genetic markers for the polled, African horn and scurs loci in *Bos indicus* cattle.

b. The operational plan for this project involves identifying sire families where the polled gene is segregating and if needed (because of ambiguity in phenotypes), generating more progeny from these bulls using advanced reproductive technologies (as MOET) for gene mapping studies. In addition, these resources need to be complemented by a wide sample of industry cattle of known ancestry. Genome scans and positional candidate gene mapping of the resource populations will help develop diagnostic gene tests to identify the underlying genetic basis of horns in cattle.

3. *Performance comparisons* – Developing the tests and breeding strategies is only half the battle, if the aim is to replace the practice of dehorning. The technology needs to be adopted by industry for it to have any impact on the numbers. This would involve breed specific strategies aimed at proving the performance capabilities of polled animals compared to horned animals.

   a. Performance data of polled and horned contemporaries in major Australian breeds can be compared based on the existing recorded data on various traits. In breeds such as the Brahman, comparable performance information may be scanty because of the excessively high numbers of horned animals. However, information can be generated in collaboration with breeders for comparison studies while implementing the breeding strategies to increase polled animals.

   b. Research to verify links between the polled gene and premature spiral deviation of the penis and preputial prolapse needs to be undertaken. If needed, practical strategies to address the problem need to be developed. This might involve developing diagnostic tests for early identification of these problems in bulls.

3.6.2 Extension strategies

Consultation with industry suggests that there are many perceptions and beliefs about the polled gene. Most breeders would welcome hard scientific evidence about these perceptions. Lack of readily accessible information on this topic seems to be one of the causes for these perceptions and any further research on the polled gene in cattle should be accompanied by simultaneous emphasis on extension strategies.

There has never been a serious industry push towards breeding polled cattle. This has been largely dictated by the individual preferences. Hence there is a need to devise extension strategies to educate breeders to make the right decisions:

1. Educating breeders on the reality of the situation and the global and local changes to codes of practice for safeguarding animal welfare.
2. Educating breeders about the need to be proactive in replacing the practice of dehorning.
3. Research results from performance comparison of polled and horned animals need to be delivered to the industry.
4. Conducting further research and delivering practical breeding strategies to counter undesirable bull soundness issues related to polled gene.
5. Projecting the undesirable effects of horned animals and quantified benefits of polled animals.
6. Educating breeders about the complexity of horns inheritance and efforts to identify the polled gene in cattle.

7. Developing an action plan to achieve the goal of reducing the number of horned animals in each breed and advocating its implementation.

4 Conclusions and Recommendations

Dehorning is an invasive procedure and there is growing awareness of animal welfare concerns. Dehorning is labour intensive in older calves and can also cause economic losses through secondary infection and mortality. Australia, the biggest exporter of beef in the world, is being proactive in advance of these growing animal welfare concerns and working to protect market access in the beef trade. Breeding polled cattle is a non-invasive welfare-friendly method of replacing the practice of dehorning. There is widespread interest in breeding for the polled condition (Appendix 6.2). However, there is a need for DNA tests because of the complexity of inheritance. Some of the northern pastoral companies (Tom Mann, personal communication) are even interested in supporting the research for developing DNA tests.

Inheritance of the polled condition in cattle is complex with at least three genes namely, polled gene (P/p), scurs gene (Sc/sc) and African horn gene (Ha/ha) segregating independently but interacting with each other to cause polled/scurred/horned phenotype. Scurs and the African horn gene are sex–influenced in their inheritance and African horn gene occurs at a higher frequency in *Bos indicus* cattle. Although several researchers have mapped the polled gene to a specific region on chromosome 1, the actual gene has not yet been identified. A currently available DNA test for identifying homozygous polled cattle is applicable only to certain *Bos taurus* breeds and can give inconclusive results.

Breeding for polled cattle has been largely directed by individual breeder perceptions and beliefs. Lack of easily available information led to largely unfounded misconceptions about poor performance associated with polled cattle. Most scientific evidence is counter to these perceptions. Although some scientific evidence links the polled gene and bull soundness issues in *Bos taurus* cattle, these problems can be addressed through planned breeding because of their low frequencies.

From breed society records, it is quite evident that many of the cattle breeds have a substantial number of horned animals. In Brahman and Santa Gertrudis breeds, around 90% of the registered cattle are horned. In Herefords (combined Hereford and Polled Hereford Societies' records), around 50% of registered cattle are horned. Variability in horned cattle numbers across various breeds and the variability in the proportions of these breeds in the national beef herd warrants development of breed specific strategies for breeding polled cattle.

It is important to undertake concerted research and extension strategies to replace the practice of dehorning through genetic options. In certain breeds, simpler strategies such as advocating the use of polled bulls can be implemented. In other breeds (with higher numbers of horned animals), specific polled bull breeding strategies need to be implemented with a long-term objective of providing proven polled bulls. These strategies will be benefited by the development of DNA tests for the identification of homozygous polled bulls. Extension strategies can concentrate on advocating the use of polled animals by publicising research results from the performance comparisons of polled and horned animals. Educating breeders about the need for being proactive in breeding polled animals is vital, given the industry's commitment to improvements in best practice for animal welfare.

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6 Appendices

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6.3 Glossary

African horn gene
A hypothesised gene controlling the inheritance of horns in cattle. It is believed to be segregating independently but with an epistatic effect on the 'polled' locus and is sex-influenced in its inheritance

Allele
One of the variant forms of a gene at a particular location on a chromosome

Bos indicus
Humped cattle; Zebu cattle breeds such as Brahmans, Borans etc.

Bos taurus
Humpless cattle; Cattle breeds of British (Hereford, Angus), European (Charolais, Simmental) and Sanga (Tuli, Africaner)

Centromere
The constricted region near the centre of a chromosome

Dehorned
Animal whose horns have been removed along with about 1 cm of skin around the base of the horn such that no regrowth occurs. It is important to note that dehorned cattle are genetically horned

Deoxyribonucleic acid (DNA)
The chemical inside the nucleus of a cell that carries the genetic instructions for making living organisms

Disequilibrium
State where genotypic frequencies at two or more loci considered jointly deviate from expected frequencies based on products of gene frequencies

Dominant
Term for an allele that masks the presence of other allele with respect to phenotypic expression when occurring together in a heterozygous individual

Epistasis
Genes at two different loci interacting to affect the expression of a single trait

Equilibrium
State in which gene and genotypic frequencies remain constant in a population from one generation to the next.

Gene
The functional and physical unit of heredity passed from parent to offspring. Genes are pieces of DNA

Genetic marker
A segment of a DNA with an identifiable physical location on a chromosome. A marker can be a gene or it can be some section of DNA. Markers are often used as indirect ways of tracking the inheritance pattern of a gene that has not yet been identified, but whose approximate location is known

Genetics
Study of heredity

Genotype
Full complement of genes influencing the phenotype for a particular trait or the genetic identity of an animal

Heterozygous
Organism that has two different alleles at the same locus affecting the same trait

Homolog
Chromosomes which are similar in that they carry most of the same loci across species having originated from a common ancestor

Homozygous
Possessing two identical forms of a particular gene, one inherited from each parent

Horn
The horn is an outgrowth of the frontal bone covered by a tough shell of modified epithelium that grows outward from the skin at the base of the horn. The horn develops from a bony core, derived from dermal and subcutaneous connective tissue that fuses to small protuberances, the horn bosses, extending from the frontal bone.

Incomplete penetrance
Phenotype associated with a particular genotype is not always expressed, perhaps due to compensating factors in the environment

Inheritance
Genetic characters transmitted from one generation to the next

Linkage
The association of genes and / or markers that lie near each other on a chromosome

Locus
Position of a single gene on a chromosome, plural is loci.

Microsatellite
Repetitive stretches of short sequences of DNA used as genetic markers to track inheritance

Multiple alleles
More than two alleles existing in the population for a particular locus

Mutation
Heritable change in the genetic material of an individual

Phenotype
Observable characteristics on the animals, determined by the individual's genotype and its environment

Polled
Animals without horns naturally

Recessive
Term for an allele that is being masked by a dominant allele

Scurs
Small rudimentary horns or short stub horns which are either rigid or loose

Sex-influenced
Trait controlled by a gene at an autosomal locus but whose phenotypic expression in the heterozygotes depends on the sex of the animal

Sex-linked
Trait controlled by genes located on the sex chromosomes

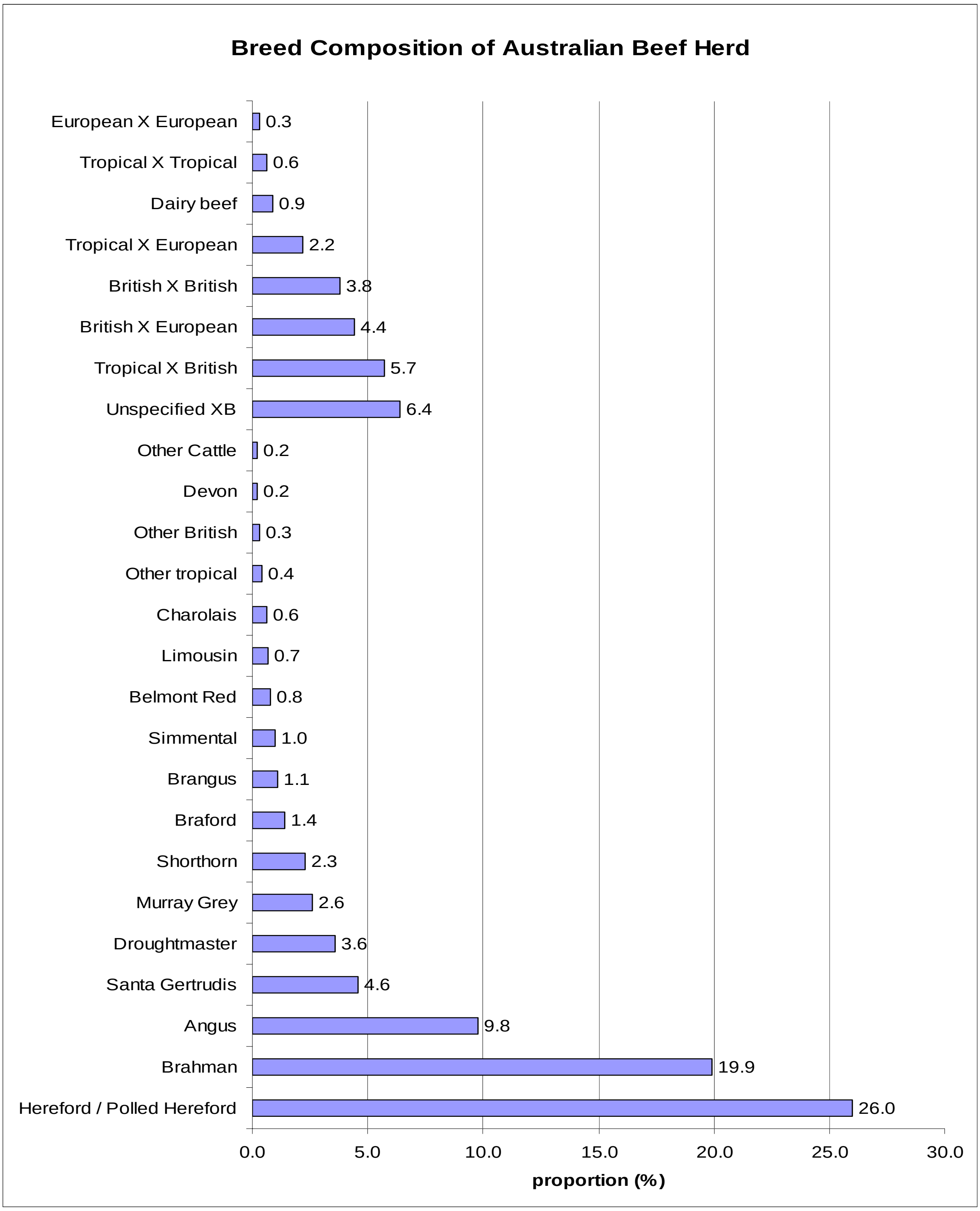
Single Nucleotide Polymorphisms (SNPs)
Common but minute variations that occur in DNA which can be used to track inheritance

Syntenic
Loci located on the same chromosome

Tipping
Tipping refers to cutting of horns leading to blunt ends. Tipping can vary from slight tipping to very severe tipping which leaves a short horn stump. Disadvantages of tipping are – a horn tipped at an angle is just as sharp as untipped horns and tipped horn continues to grow with a blunted end.

6.4 Proportion of various breeds in the Australian beef herd

(Source: MLA final report prepared by Sillar Associates, Trurobe Pty Ltd & John James on project number TR.080, March 2000)



6.5 Breed-wise number of horned, scurred and polled cattle (with known horns status) registered during recent years

Table 8. Number of Horned, Scurred and Polled cattle registered during recent years in various breeds – Hereford (both Hereford and Polled Hereford combined)

Year	Horned	Scurred	Polled	Total	Horned%	Scurred%	Polled%
1995	30539	380	31597	62516	49	1	51
1996	28801	367	29474	58642	49	1	50
1997	26530	383	27478	54391	49	1	51
1998	24050	325	24649	49024	49	1	50
1999	24078	338	24468	48884	49	1	50
2000	23083	456	24473	48012	48	1	51
2001	21261	500	22853	44614	48	1	51
2002	18983	447	22895	42325	45	1	54
2003	16284	385	20615	37284	44	1	55
2004	14603	262	18407	33272	44	1	55
total	228212	3843	246909	478964	48	1	52

*Percentages are rounded to nearest number

Fig 5. Trends in horned, scurred and polled cattle percentages in cattle with known horns status during recent years – Hereford

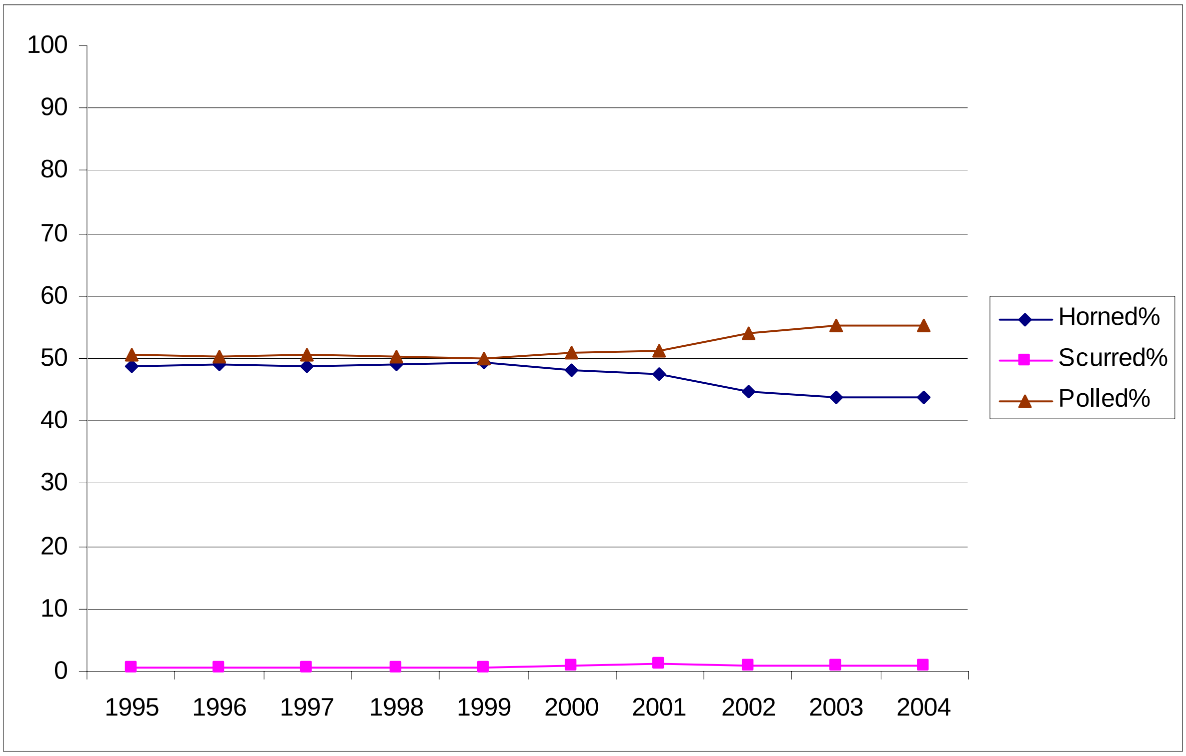


Table 9. Number of Horned, Scurred and Polled cattle registered during recent years in various breeds - Brahman

Year	Horned	Scurred	Polled	Total	Horned%*	Scurred%*	Polled%*
1995	18843	1	1863	20707	91	0	9
1996	18968	1	2021	20990	90	0	10
1997	20750	2	2212	22964	90	0	10
1998	20668	2	2348	23018	90	0	10
1999	20765	11	2531	23307	89	0	11
2000	19422	31	2380	21833	89	0	11
2001	17689	147	2281	20117	88	1	11
2002	17025	184	2358	19567	87	1	12
2003	15212	135	1955	17302	88	1	11
2004	13316	187	1700	15203	88	1	11
total	182658	701	21649	205008	89	0	11

*Percentages are rounded to nearest number

Fig 6. Trends in horned, scurred and polled cattle percentages in cattle with known horns status during recent years – Brahman

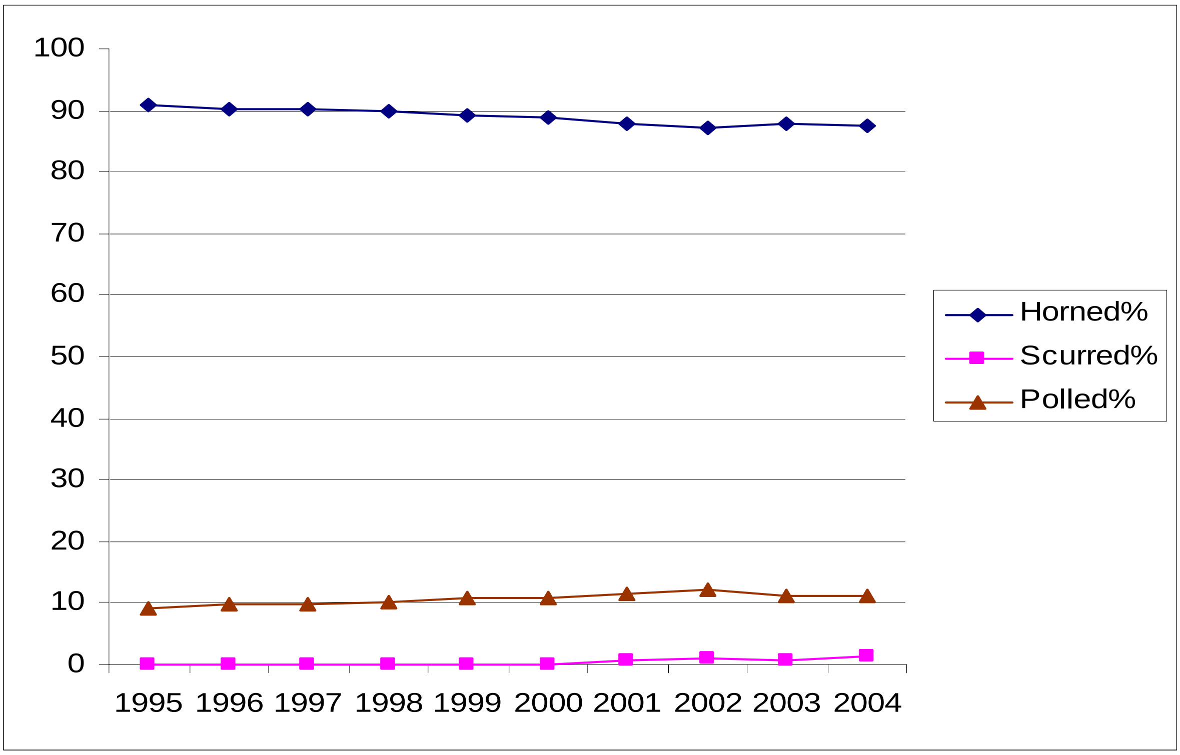


Table 10. Number of Horned, Scurred and Polled cattle registered during recent years in various breeds - Santa Gertrudis

Year	Horned	Scurred	Polled	Total	Horned%*	Scurred%*	Polled%*
1995	16078	192	1282	17552	92	1	7
1996	15963	248	1396	17607	91	1	8
1997	15090	224	1390	16704	90	1	8
1998	14316	208	1402	15926	90	1	9
1999	14598	213	1426	16237	90	1	9
2000	15266	223	1532	17021	90	1	9
2001	15007	203	1506	16716	90	1	9
2002	14058	198	1456	15712	89	1	9
2003	12979	151	1134	14264	91	1	8
2004	14531	68	349	14948	97	0	2
total	147886	1928	12873	162687	91	1	8

***Percentages are rounded to nearest number**

Fig 7. Trends in Horned, Scurred and Polled cattle percentages in cattle with known horns status during recent years – Santa Gertrudis

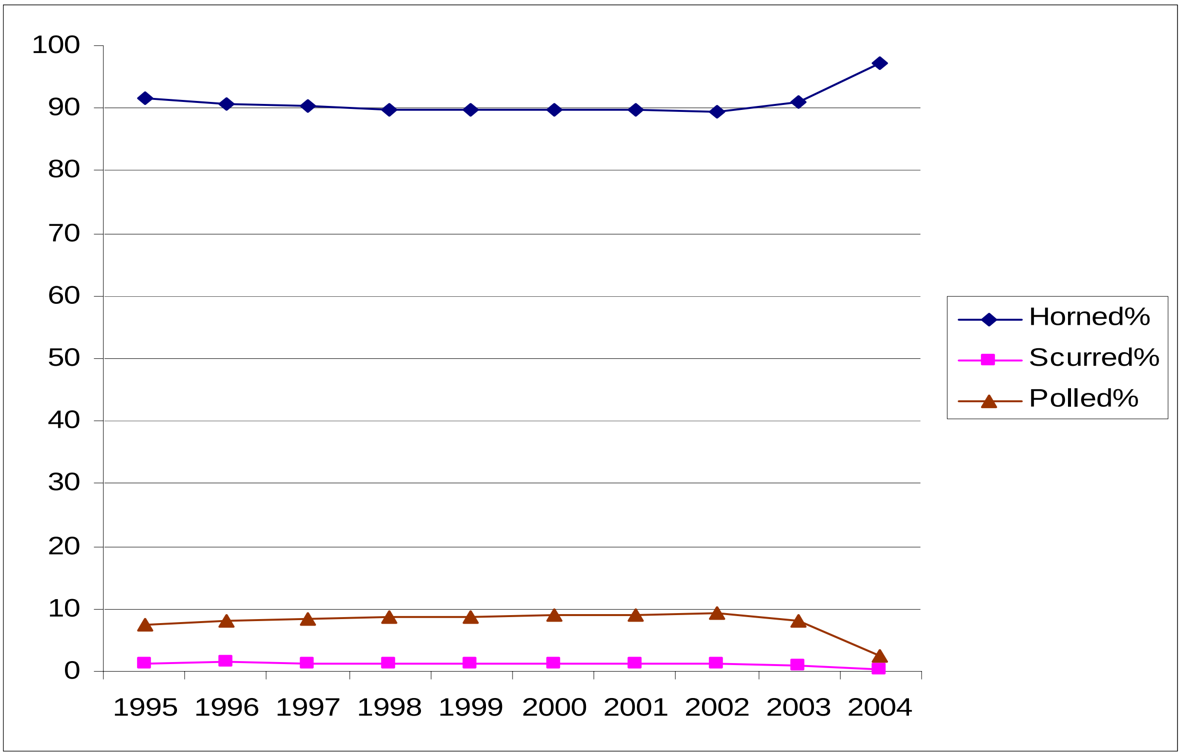


Table 11. Number of Horned, Scurred and Polled cattle registered during recent years in various breeds – Droughtmaster

Year	Horned	Scurred	Polled	Total	Horned%*	Scurred%*	Polled%*
1995	970	266	3004	4240	23	6	71
1996	802	433	5127	6362	13	7	81
1997	870	516	5430	6816	13	8	80
1998	1010	559	5445	7014	14	8	78
1999	1228	605	5757	7590	16	8	76
2000	1065	616	6821	8502	13	7	80
2001	918	656	6683	8257	11	8	81
2002	1364	680	6897	8941	15	8	77
2003	1313	674	7181	9168	14	7	78
2004	789	527	5639	6955	11	8	81
total	10329	5532	57984	73845	14	7	79

*Percentages are rounded to nearest number

Fig 8. Trends in Horned, Scurred and Polled cattle percentages in cattle with known horns status during recent years – Droughtmaster

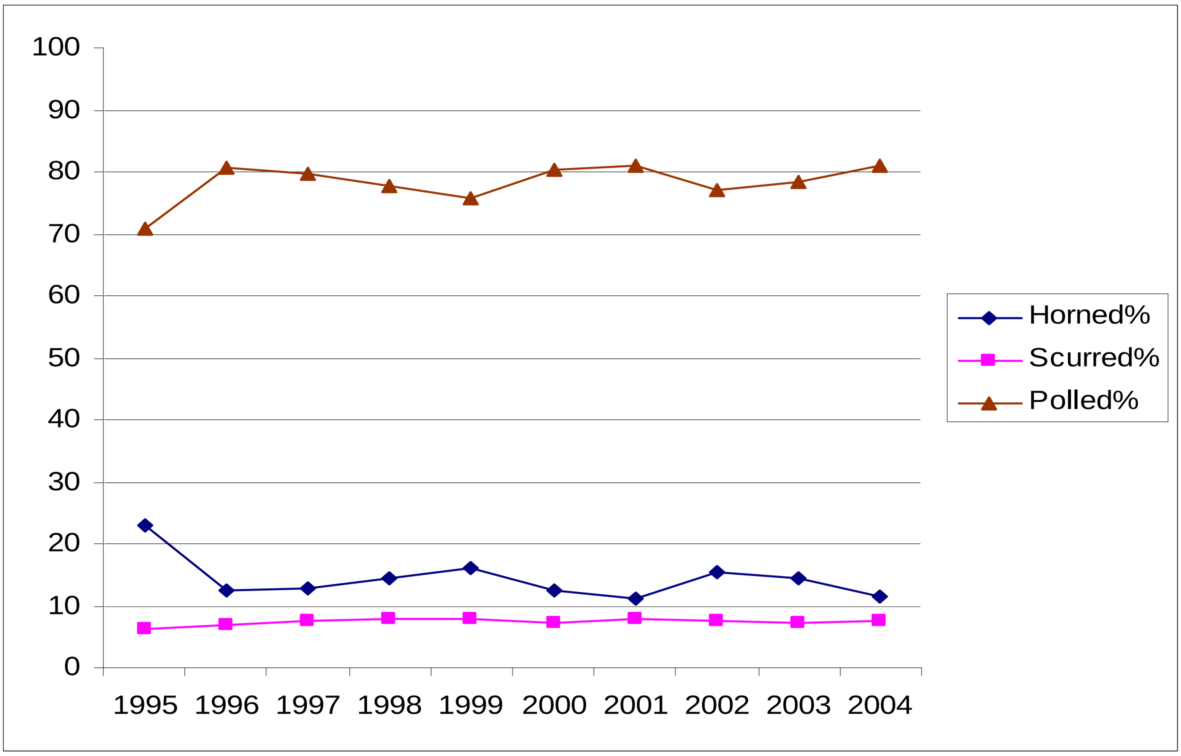


Table 12. Number of Horned, Scurred and Polled cattle registered during recent years in various breeds – Braford^

Year	Horned	Scurred	Polled	Total	Horned%*	Scurred%*	Polled%*
1995	0	38	174	212	0	18	82
1996	0	32	195	227	0	14	86
1997	0	44	247	291	0	15	85
1998	0	91	693	784	0	12	88
1999	0	86	892	978	0	9	91
2000	0	93	856	949	0	10	90
2001	0	95	870	965	0	10	90
2002	0	104	876	980	0	11	89
2003	0	96	782	878	0	11	89
2004	0	70	663	733	0	10	90
total	0	749	6248	6997	0	11	89

***Percentages are rounded to nearest number**
^high percentage of unknowns in the registered cattle

Fig 9. Trends in Horned, Scurred and Polled cattle percentages in cattle with known horns status during recent years – Braford

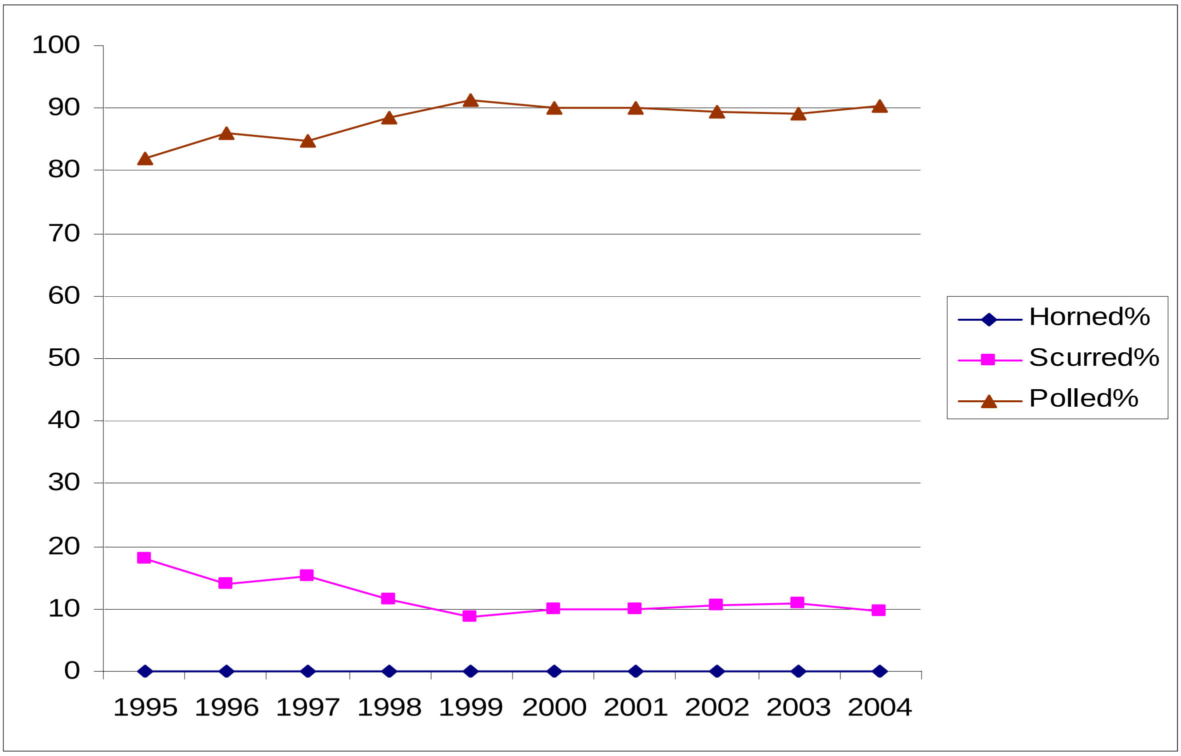


Table 13. Number of Horned, Scurred and Polled cattle registered during recent years in various breeds - Brangus

Year	Horned	Scurred	Polled	Total	Horned%*	Scurred%*	Polled%*
1995	10	0	2162	2172	0	0	100
1996	16	0	2317	2333	1	0	99
1997	53	0	2625	2678	2	0	98
1998	12	0	2677	2689	0	0	100
1999	6	0	2708	2714	0	0	100
2000	11	0	3413	3424	0	0	100
2001	16	0	2777	2793	1	0	99
2002	27	0	2803	2830	1	0	99
2003	15	0	2171	2186	1	0	99
2004	8	0	1627	1635	0	0	100
total	174	0	25280	25454	1	0	99

***Percentages are rounded to nearest number

Fig 10. Trends in Horned, Scurred and Polled cattle percentages in cattle with known horns status during recent years – Brangus

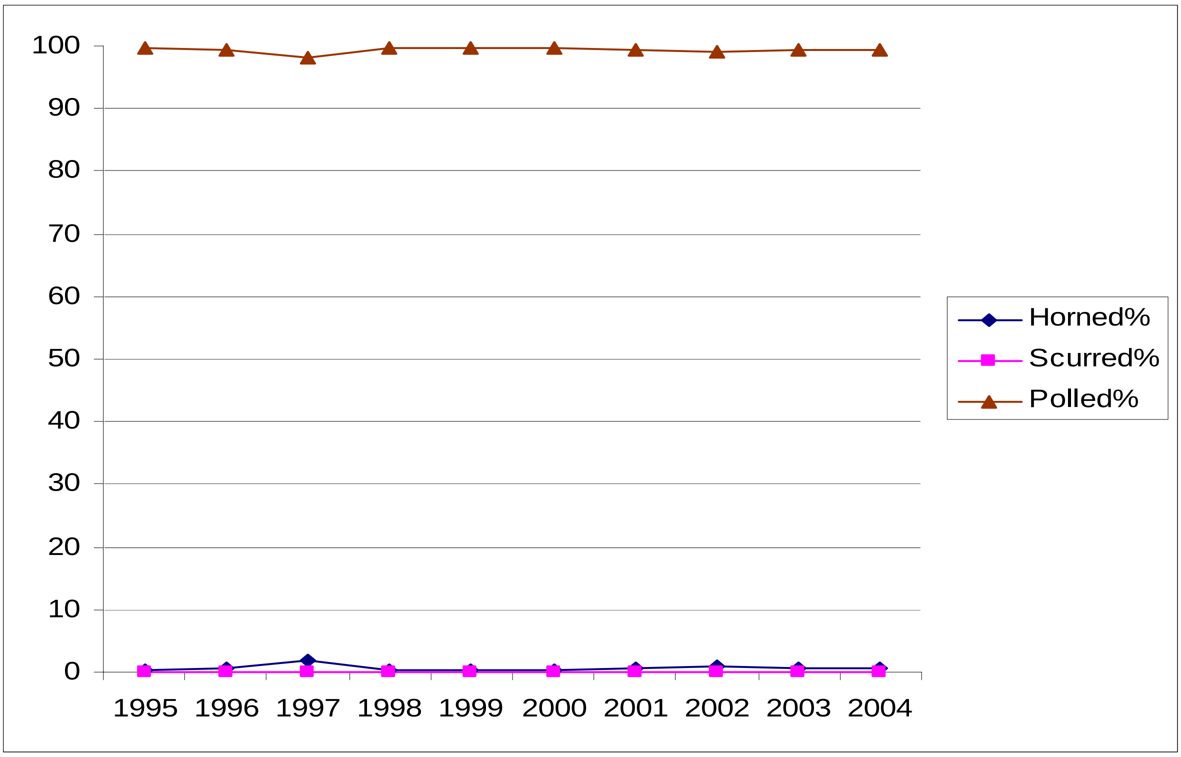


Table 14. Number of Horned, Scurred and Polled cattle registered during recent years in various breeds – Simmental^

Year	Horned	Scurred	Polled	Total	Horned%*	Scurred%*	Polled%*
1995	5	44	1563	1612	0.3	2.7	97.0
1996	6	19	1365	1390	0.4	1.4	98.2
1997	3	21	1114	1138	0.3	1.8	97.9
1998	1	38	796	835	0.1	4.6	95.3
1999	1	33	800	834	0.1	4.0	95.9
2000	0	20	870	890	0.0	2.2	97.8
2001	1	38	853	892	0.1	4.3	95.6
2002	0	39	800	839	0.0	4.6	95.4
2003	0	33	731	764	0.0	4.3	95.7
2004	0	37	1020	1057	0.0	3.5	96.5
total	17	322	9912	10251	0.2	3.1	96.7

*Percentages are rounded to nearest number
^high percentage of unknowns in the registered cattle

Fig 11. Trends in Horned, Scurred and Polled cattle percentages in cattle with known horns status during recent years – Simmental

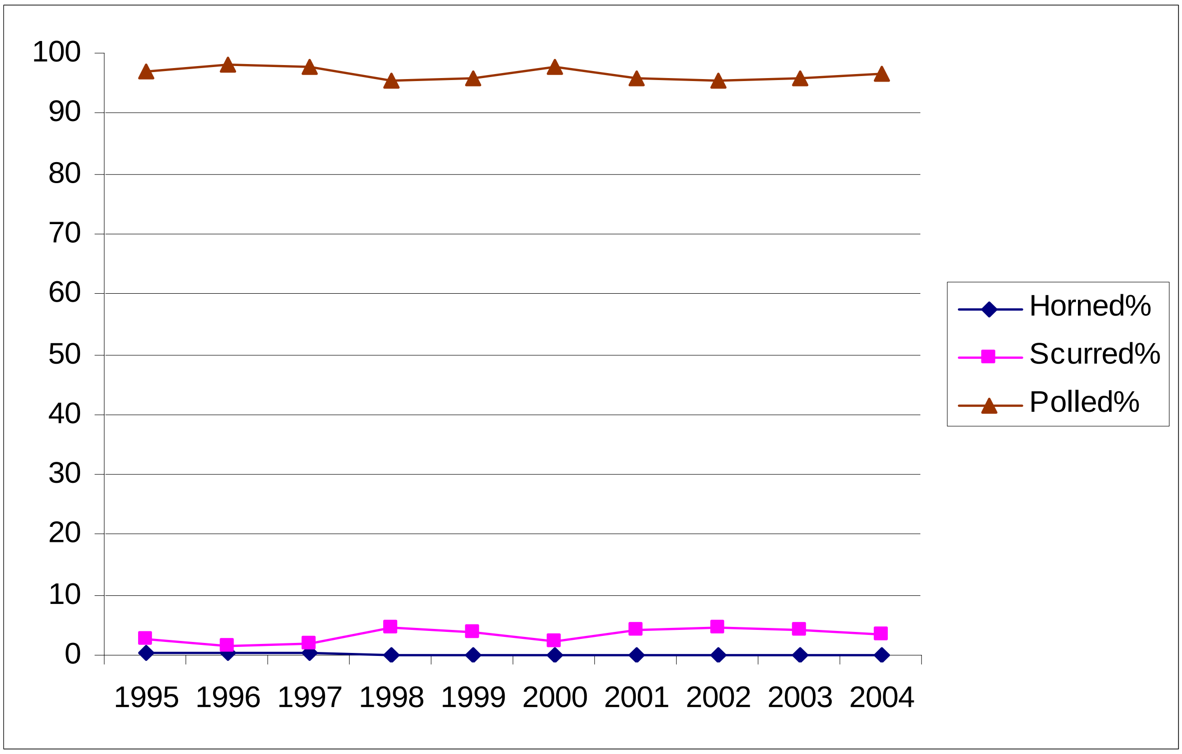


Table 15. Number of Horned, Scurred and Polled cattle registered during recent years in various breeds – Belmont Red^

Year	Horned	Scurred	Polled	Total	Horned%*	Scurred%*	Polled%*
1995	174	7	139	320	54	2	43
1996	435	17	273	725	60	2	38
1997	1458	50	618	2126	69	2	29
1998	1289	102	770	2161	60	5	36
1999	454	132	1071	1657	27	8	65
2000	103	56	233	392	26	14	59
2001	283	110	690	1083	26	10	64
2002	439	139	752	1330	33	10	57
2003	151	2	140	293	52	1	48
2004	308	37	341	686	45	5	50
total	5094	652	5027	10773	47	6	47

*Percentages are rounded to nearest number
^high percentage of unknowns in the registered cattle

Fig 12. Trends in Horned, Scurred and Polled cattle percentages in cattle with known horns status during recent years – Belmont Red

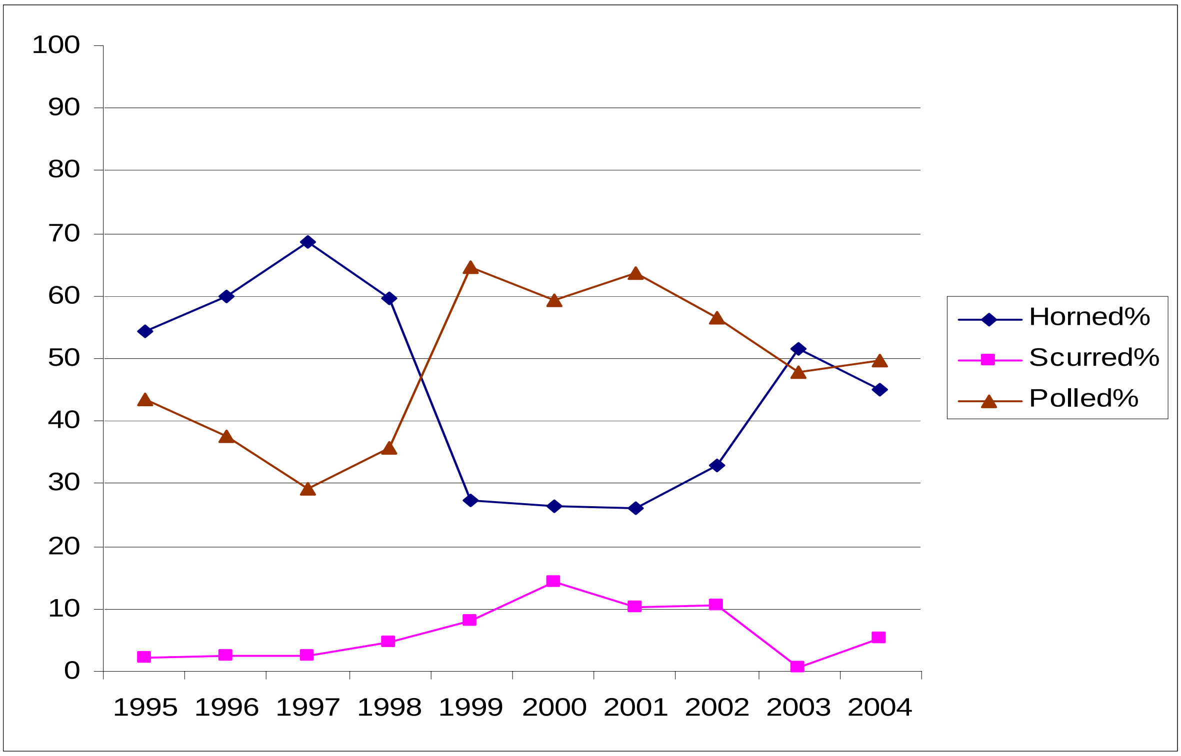


Table 16. Number of Horned, Scurred and Polled cattle registered during recent years in various breeds – Limousin

Year	Horned	Scurred	Polled	Total	Horned%*	Scurred%*	Polled%*
1995	9368	189	2254	11811	79	2	19
1996	9983	171	2362	12516	80	1	19
1997	7528	109	2116	9753	77	1	22
1998	4709	112	1310	6131	77	2	21
1999	4206	85	1439	5730	73	1	25
2000	4041	118	1405	5564	73	2	25
2001	4303	117	1651	6071	71	2	27
2002	4289	115	1605	6009	71	2	27
2003	3606	106	1702	5414	67	2	31
2004	3828	123	1916	5867	65	2	33
total	55861	1245	17760	74866	75	2	24

***Percentages are rounded to nearest number**

Fig 13. Trends in Horned, Scurred and Polled cattle percentages in cattle with known horns status during recent years – Limousin

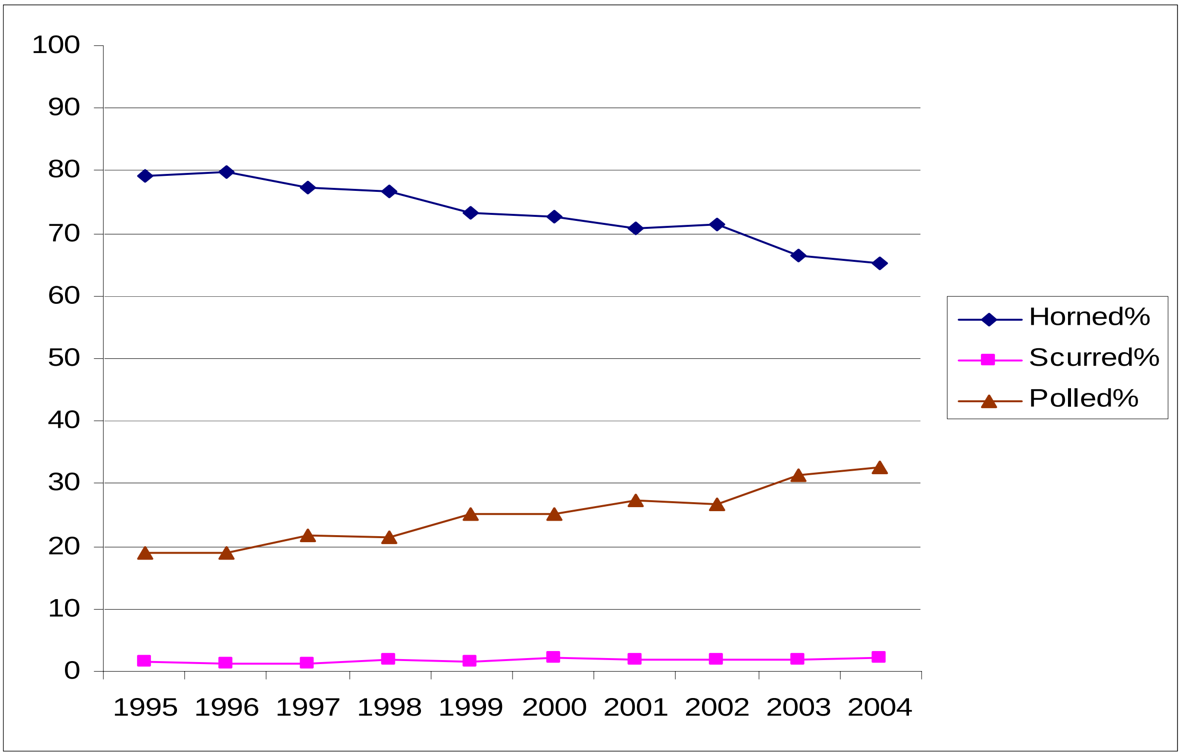


Table 17. Number of Horned, Scurred and Polled cattle registered during recent years in various breeds – Charolais

Year	Horned	Scurred	Polled	Total	Horned%*	Scurred%*	Polled%*
1995	1280	111	1543	2934	44	4	53
1996	1569	75	1774	3418	46	2	52
1997	1444	114	1730	3288	44	3	53
1998	1444	123	1667	3234	45	4	52
1999	1992	159	1665	3816	52	4	44
2000	2507	161	1852	4520	55	4	41
2001	3008	159	1871	5038	60	3	37
2002	2708	141	2045	4894	55	3	42
2003	2759	119	2066	4944	56	2	42
2004	2797	152	1876	4825	58	3	39
total	21508	1314	18089	40911	53	3	44

***Percentages are rounded to nearest number**

Fig 14. Trends in Horned, Scurred and Polled cattle percentages in cattle with known horns status during recent years – Charolais