REPORT

Assessing Reproductive and Breeding Techniques in Organic Agriculture using Cattle Breeding as an Example

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Contents:

1. Introduction

Organic farming is characterized by the careful stewardship of nature and the environment. Because agriculture, as a means of cultivation, necessitates an intrusion in nature, the practitioners of Organic Agriculture are required to demonstrate a high level of care and an ethical awareness. This responsibility is of particular importance when it comes to animal husbandry. For these reasons, several requirements regarding animal selection and the use of reproductive techniques have been formulated and introduced into the laws and guidelines of organic farming organizations[1].

Increased success due to reproductive techniques

Livestock breeding has made a major contribution to organic farming productivity in recent decades. Improvements mainly concern production characteristics (e.g., quantities of milk, meat and eggs). The development and application of reproductive techniques is one of the main catalysts for these increases. Reproduction rates can be enhanced both on the male as well as on the female side.breeding programs are becoming more efficient, the accuracy of breeding value estimates is higher, and there is usually a shortening of the interval between generations.

Organic farming has drawn the line at artificial insemination[2], meaning that this procedure is tolerated, but the practice of embryo transfers is prohibited at the on-farm level. In Switzerland it is even forbidden to raise bulls (or make use of their sperm), if they are born of an embryo transfer mating[3]. Nevertheless, organic farming will always be connected to reproduction technologies that do not accord with the principles of the organic movement, because most breeding animals or their ancestors originate from conventional agriculture. Not until organic farmers develop, apply, and enforce breeding strategies that stem from or are designed for organic agriculture can those unsuitable breeding methods be excluded from the beginning.

Table 1: Reasons for Culling of Performance Tested Dairy Cows in Germany (total since 1990) from 1979 to 2005 (in %)[4]

	Year								
Reasons for Culling	1979	1989	1994	2000	2001	2002	2003	2004	2005
Sold to Slaughter	6.1	7.9	9.8	13.0	9.4	10.6	10.1	12.0	14.4
Age	10.4	8.6	5.4	1.5	1.6	1.5	1.4	1.4	1.4
Low Performance	14.2	9.0	8.0	6.7	6.5	6.3	5.7	6.0	5.8
Infertility	29.8	27.8	20.0	17.1	17.5	17.8	19.5	19.6	18.5
Misc. Illness	3.2	3.7	5.6	11.5	8.5	9.1	9.5	9.1	8.9
Udder disease	7.8	12.0	15.1	17.6	16.8	17.3	17.0	16.0	16.4
Milk yields	1.7	2.0	2.0	2.2	2.1	2.1	2.0	2.4	2.5
Hooves/Appendages	4.3	6.3	7.6	8.5	9.9	9.6	10.4	10.2	10.7
Metabolic disorders	-	-	-		3.7	3.6	4.2	4.9	5.0
Disease/Infertility total	*46.8*	*51.8*	*50.3*	*56.9*	*58.5*	*59.5*	*62.6*	*62.2*	*62.0*
Other	21.2	22.8	26.4	22.0	24.1	22.2	20.2	18.4	16.4

[1] For example: Bioland Regulations (2006, in German): http://www.bioland.de/fileadmin/bioland/file/bioland/erzeuger-richtlinien.pdf

[2] Regulation (EWG) Nr. 2092/91

[3] BIO SUISSE Regulations (2006, in German): http://www.bio-suisse.ch/media/de/pdf2007/rl-ws/rl_2007_d.pdf

[4] From: F. Augsten: "Rinderzucht – Quo vadis?", in: Agrarbündnis: Landwirtschaft 2002. Der kritische Agrarbericht. Rheda-Wiedenbrück. pp. 134-138 (updated); Source: VIT-Jahresberichte 1979-2005.

Problems with health and longevity

Organic farming places the greatest emphasis on the functional characteristics (health, fertility and efficiency) for animal breeding. In particular, health, longevity, and a milk production level that is adapted to regional characteristics are very high priorities. This corresponds to the desires and demands of consumers, who prefer high-quality products from healthy animals receiving a minimal amount of medication and veterinary treatments. Unfortunately, health and fertility parameters generally have low levels of heritability (h^2); in addition, there are data gathering and implementation problems. Furthermore, it is not possible to simultaneously enhance production traits (milk and meat performance) and functional traits through breeding, because a negative correlation exists between these two sets of characteristics. An improvement of functional traits through breeding is urgently needed, however, as the average lifespan of cows in Germany in 2003 was only 5.4 years.[5] The number of cullings related to illness and infertility of performance tested dairy cows in Germany has steadily increased (see Table 1).

1.1 The Debate on Biotechnology

With the development of new genetic methods that complement conventional breeding value estimation methods, models such as Marker Assisted Selection (MAS) are being developed. They might be able to enhance efficiency of the selection for functional traits, such as longevity. Depending on the breeding program and the nature of the tests, genetic methods are usually applied in combination with reproductive techniques (especially embryo transfer (ET)). These methods and the selection strategies based on them are not applied at the farm level, but by breeding organisations. Hence, as long as organic farming is linked with conventional breeding, it will remain affected by these trends.

The use of biotechnology in organic animal breeding, applied both directly (e.g., artificial insemination (AI)) and indirectly (e.g., embryo transfer), is very controversially discussed, and thus, there are significant differences in the regulations on organic production between several European countries such as Germany, the Netherlands, Switzerland, and Austria. The complexity of the topic can even lead to a difficulty in understanding, which further complicates the discussions. A survey given to farmer associations[6] showed there was a high demand for discussion and education regarding the use of reproductive technologies in animal breeding in organic farming.

To ensure that the above-mentioned goals, such as fitness and high lifetime milk production levels, can be achieved through organic farming methods, there needs to be a consistent line of argumentation. In addition, future developments must be taken into consideration, in order to be able to discuss any technology that might be used within the framework of organic farming before it is adopted.

The conclusions presented here are a summary of the discussions of the "Breeding Techniques" Working Group of the “Organic Animal Breeding Network”. Primarily the following points were discussed:

[5] ADR (2002): Jahresbericht der Arbeitsgemeinschaft Deutscher Rinderzüchter e.V., Bonn.

[6] B. Bapst; A. Spengler Neff; R. Saner: “Werden die heutigen Rinderzuchtprogramme den Anforderungen des ökologischen Landbaus gerecht?”, in: Beiträge zur 7. Wissenschaftstagung zum ökologischen Landbau, Vienna 2003.

- Summary of the status quo with regard to the use of reproductive techniques in Germany, Switzerland and the Netherlands, and the resulting implications for organic agriculture.

- Discussion on and appraisal of the various techniques from the perspective of organic agriculture.

- Possibilities for using these appraisals in the production regulations for organic farming.

The working group consisted of the following experts in organic animal breeding from Germany and Switzerland: Dr. Frank Augsten, Prof. Dr. Ton Baars, Beat Bapst, Dr. Anita Idel, Christoph Metz, Dr. Günter Postler, Dr. Ulrich Schuhmacher, Stephan Scholz, and Esther Zeltner. In addition, Prof. Dr. Georg Erhardt and Dr. Klaus Peter Wilbois attended as guest speakers.

1.2 Why does Organic Farming Need Adapted Breeding Programs?

The enormous progress made with regard to production traits (e.g., milk yield) has pushed traits like health, fertility and product quality, which are important in organic farming, into the background, and this has worsened the quality of breeds in these regards. Only in recent years have functional traits begun to regain importance. In addition, as mentioned above, the introduction of specific reproductive techniques is becoming a more and more important issue. Furthermore, organic farming is characterized by a great diversity, whereas conventional livestock production, on the other hand, is becoming more and more uniform, because external inputs (e.g., feed and medications) are speeding up the process of standardization.

Because of the diversity in organic farming, which arises out of the variety of different environmental conditions, a site-related approach to breeding is a very high priority. This in turn implies that a wide range of animal breeds should be available to organic farmers.

The arguments above all point to the need for dairy cattle breeding that is adapted to the specific requirements of organic agriculture. There are several ways that this can be achieved:

a. Through the development of an adapted breeding program for organic farmers
b. By partitioning an existing breeding program in order to adapt a specific segment of it to organic farming
c. By a conscious decision (of breeding organisations) to maintain a highly varied gene pool in existing breeding programs, such that specific animals can be selected that are suited to the needs of individual organic farms.

For alternatives a. and b., it is important that a unique breeding program actually can be established, which specifically works toward the breeding objectives of organic farming through mating and selection. In addition, the bred populations (or subpopulations) would have to be large enough that progress in the desired traits could be made without an unacceptable level of risk of inbreeding. If specific breeding strategies are developed for organic farming, the use of unwanted or only partially accepted reproductive techniques and selection strategies can be excluded from the outset. For example, in Switzerland, the Swiss Fleckvieh breeding organisation,[7] the largest provider of semen,[8] and a farmer interest group (IG Swiss Fleckvieh[9])

[7] SFZV (2006): http://www.fleckvieh.ch

have all committed to refrain from the use of ET for breeding AI-bulls in one segment of their program (Swiss Fleckvieh), so that organic breeders can use this gene pool without hesitation.

2. Assessment of Reproductive and Breeding Techniques

Through well applied animal breeding methods, the frequency of desirable alleles or combinations of alleles can be increased, while the undesirable ones are reduced. The use of reproductive techniques enables breeders to get a higher number of offspring from certain animals with very desirable traits. This, in turn, means that breeding goals can be achieved faster. On the other hand, the degree of inbreeding within the active population or subpopulation tends to rise, which results in a reduction of genetic variation. The more narrowly defined the goals of breeding are (i.e., the fewer the traits that breeders are selecting for) the faster they can be achieved; if the goals are to select for multiple traits in different categories, the process will take longer.

These causal relationships apply to all types of breeding activities. However, reproductive techniques play a very important role. There could be an additional, technology-related selection that results in the undesired outcome that sperms, oocytes, or embryos that would not have survived the natural fertilization process and subsequent embryo growth stages are propagated. Because those individuals are not exposed to the environment the whole time, it can be hypothesized that germ cells and embryos produced this way will have negative fertility and fitness characteristics later in life.

The tables below provide an assessment and evaluation of the various reproductive techniques that exist or are foreseen for the future, from the perspective of organic farming. The tables include the pros and cons of each individual technique and a consideration of whether the technique can be adopted by organic farmers or should be kept separate from organic farming. A final evaluation is given for each technique by assigning it to one of the following categories: desirable, tolerated, tolerated for a limited time (problematic), or rejected.

The statements listed for each of the various techniques are designed to provide a platform on which organic farming associations can continue to discuss these issues. They can also serve a useful purpose in decision making on the preparation/revision of guidelines and regulations for organic farming regarding the direct or indirect use of reproductive and breeding techniques.

The statements are not referenced; they reflect the discussions of the working group and highlight where problems arise and where they do not. In order to maximize their efforts, the working group focused on the example of cattle breeding. Conclusions for other animals can certainly be drawn from this work. Although certain techniques are not applied in the same way for all species/types of animals, the basic principles that apply are the same in all cases.

[8] Swissgenetics (2006): http://www.swissgenetics.ch/
[9] IG Swiss Fleckvieh (2006): http://www.swissfleckvieh.ch

2.1 Natural Mating

Natural Mating	
Description	This is the natural method of reproduction, in which the cow is fertilized by a bull. In Germany, Switzerland, and Austria, 10 to 20% of all cows are fertilized in this way, by being mounted. Natural mating is more widespread in suckler cow herds than in dairy cows. This method of reproduction is as common in organic production as in conventional.
Pro	• The only natural method of reproduction • If a bull is purchased or used for breeding, it is possible to find out background information about the animal and its farm environment, such as: basis of its diet, stall/pasture conditions, and animal-human interaction. • The fertility of the cows is better when there is a bull in the herd: the estrus is more obvious, animals that don’t show their heat are easier to identify, and the rate of impregnation is also higher. • Natural selection occurs based on the good character of the bulls. • The father is present in the herd: a natural family unit (a small number of male animals and many female animals) can be maintained. • Higher genetic variety can be maintained (from the point of view of the entire population), because individual fathers are not intensively used.
Contra	• Slower progress through breeding: fewer offspring, which means that progeny testing is extremely difficult or, in some cases, impossible, with the result that the security of inheritance decreases. • For cattle breeders there is a risk of accidents with breeding bulls, and potential dangers exist in association with pasturing them. • Uncertainty with regard to genetic deficiencies, or the delayed realization of genetic deficiencies • Risk of spreading mounting diseases. • The use of natural mating alone makes corrective pairing difficult.
Consequences of Rejection	Rejection of this technique is not under discussion.
Alternatives	• Artificial insemination
Evaluation	Desirable

2.2 Artificial Insemination (AI)

Artificial Insemination (AI)	
Description	Insemination of female cows through the use of a catheter containing thawed sperm. Sperm collection: The bull (the sperm donor) is excited to the point of ejaculation through an artificial cow’s back or a synthetic vagina. The ejaculate is examined in regard to its potential to fertilise, and then it is divided into doses, conserved, and put into storage. The doses of sperm can be preserved and stored for a long time.
Pro	• A more targeted progeny testing with more precise estimates of breeding values is more feasible • More breeding success, also with regard to functional traits

	• It is easier to select on the male side by using progeny testing • No danger injuries by bulls • No infection with mounting diseases • Pairings specific to a certain cow are possible • Semen is available for breeding worldwide • It is easier to crossbreed • It is easier to split herds into dairy and meat producing animals • It is possible to collect and save semen of endangered breeds • Breeding bulls do not need to be transported.
Contra	• Unnatural process • Danger that breeding is not adapted to the local environment • The reproductive cycles of the cow are interpreted less precisely, which can lead to mistaken insemination. • Breeders depend on breeding organisations and providers of semen • Unnoticed genetic deficiencies can become widespread. • Danger of narrowing the gene pool of the population • Antibiotics are often used to “conserve” doses of sperm. • Bulls can be used globally, which increases the danger that existing gene x environment-interactions will be ignored. • Limitation of individual pairings through the reduction of bulls available • The character of the bull is not taken into account. • Diseases can be spread by the person doing the insemination. • Possibility of mistaken selection due to technical problems • Only bulls whose sperm can be frozen are able to contribute.
Consequences of Rejection	• Rejection would be out of touch with reality and is not achievable in practice. • Less breeding progress could be made with regard to certain traits. • Exchange of semen over a large distance would no longer be possible or would require costly animal transports. • Possibility that mounting diseases appear
Alternatives	• Natural mating (breeding bulls within herds or kept in cooperatives of breeders) • Breeding strategies that use both AI and natural mating as appropriate
Evaluation	Tolerated (to desirable)

2.3 Cycle control / Synchronization of Cycles

Cycle control / Synchronization of Cycles	
Description	Hormonal treatment of an animal or a herd, in order to increase the rate of pregnancy, or in order to get an entire group of animals into the same fertility and calving cycles
Pro	• Simplification of the management of specific production systems, for example, having a birthing season in combination with a break in milking for a pure pasturing system • Easier to spot cows’ estrus
Contra	• Use of hormones is a systematic interference and does not align with the principles of organic agriculture. • Seasonal peaks in work and seasonal ebbs and flows in production

	• False selection: animals that are less fertile and animals that respond well to external hormonal influences are selected for. • Animals with irregular cycles must be separated from the herd.
Consequences of Rejection	• Rigid systems that are fixed to a particular rhythm are less feasible.
Alternatives	• Strict selection for fertility • Selling or culling animals that do not fit into the system cycles • Improving the fertility of the herd through the integration of breeding bulls • It is possible to get herds synchronized in a wider spectrum of calving and fertility rhythms through consistent and reliable selection and management measures, without the use of hormones
Evaluation	To be rejected (Hormone treatments are only allowed in certain cases for therapeutic purposes.)

2.4 Superovulation and Embryo Transfer (ET)

Superovulation and Embryo Transfer (ET)	
Description	Through a special hormone treatment, the maturing and ovulation of several oocytes can be triggered. Thereafter artificial insemination takes place. The resulting embryos (in the morula state) are taken from the mother (flushing). The individual embryos can be preserved or placed in a surrogate animal, which has been induced into the appropriate stage of its cycle using hormones.
Pro	• Increase in the reproductive rates of cows that are very good in particular traits (Increase in breeding progress on the female side) • “Infertile” animals, (for example, those that have undergone cesarean sections), can still be used. • Further techniques are brought forward.
Contra	• See contra arguments for AI and cycle control. • Use of hormones for the donor animal as well as the receiving animal • Breeding is possible with “infertile” animals. • Selection can be determined by the technology. • Danger of narrowing the gene pool of the population • From the perspective of breeders, it is no longer necessary to increase the lifespan of a cow in order to get enough offspring.
Consequences of Rejection	• Possible decrease in breeding progress for particular traits
Alternatives	• Targeted traditional breeding practices
Evaluation	To be rejected on farm level (Beyond the farm level it is unavoidable.)

2.5 Ovum pick-up / In vitro Fertilization

Ovum pick-up / In vitro Fertilization	
Description	In the first step of this process, unfertilized oocytes are taken from the ovaries of the female animals. This is either done by making an insertion in the animal or directly after the cow has been slaughtered. Oocytes can also be taken from animals that have not reached full reproductive maturity. The

	egg cells are then cultivated and undergo a maturing process. After that they are fertilized in a nutrient solution using prepared sperm and cultivated further until they reach the morula- or blastocyst stage. As with ET, the individual embryos can be placed in a surrogate animal, which has been brought into the appropriate stage of gestation through the use of hormones. This practice is not currently in use.
Pro	• Shortening of the interval between generations and an increase in the number of offspring from the female side, which can lead to speedier results with regard to selection for specific traits. • If the oocytes are obtained from a living animal, the use of hormones (for the donating animal) is not necessary (in contrast to ET).
Contra	• Fertilization of the egg cells takes place outside of the body of the animal in an artificial culture medium. This raises concerns about possible damage. • Statistics show that calves who originate from in vitro fertilization are often oversized and overweight and cannot be born without cesarean sections. • Danger of a narrowing of the gene pool of the population • Selection can be determined by the technology.
Consequences of Rejection	• See embryo transfer.
Alternatives	• See embryo transfer.
Evaluation	To be rejected

2.6 Cloning Techniques

Cloning Techniques	
Description	Cloning produces individuals that are nearly genetically identical by splitting embryos or transferring the cell nucleus in the oocyte.
Pro	• Multiple use of animals with identical, good genetic characteristics
Contra	• Cloning paves the way for genetic manipulation. • Products from cloned animals would not be accepted by consumers of organic products. • Progress through breeding cannot be made by cloning. • Expensive • Not ready for implementation
Consequences of Rejection	None.
Alternatives	Traditional breeding practices
Evaluation	To be rejected

2.7 Sex Determination

Sex Determination	
Description	Sex determination and the subsequent separation take place through an examination of the semen (flow cytometry). This method is implementable today, but the technology is still quite expensive.

Pro	• If breeding is targeted to achieve a narrow set of goals, which are dependent on the sex of the animal, selection is more successful. • The greater the intensity of the selection rate, the greater the level of progress in breeding.
Contra	• Expensive • Promotes extreme specialization in animal husbandry • Possible damage to semen
Consequences of Rejection	• If the sexing of sperm becomes a widespread practice, then a rejection of the technique could mean that far fewer sperms are available. • Ethical concerns arise if male calves of dairy breeds are culled directly after birth.
Alternatives	• Working towards breeding objectives that are less specialized • Open up new distribution channels through clever marketing (for example, the meat of male Jersey calves has been successfully sold as a specialty by certain Swiss producers)
Evaluation	To be rejected

2.8 Genome Analysis, Genomic Selection (GS) and Marker- Assisted Selection (MAS)

Genome Analysis, Genomic Selection (GS) and Marker-Assisted Selection (MAS)	
Description	Analysis of the genetic structure of the genome, or, in other words, finding markers on the level of DNA (like “quantitative trait loci” (QTLs) for Marker assisted selection or single nucleotide polymorphisms (SNPs) for genomic selection) that are strongly associated with certain phenotypic traits, using molecular genetic methods. The information is then used to make decisions on selection (MAS, GS). Method is very often associated with the frequent use of reproductive techniques.
Pro	• Reliability of the assessment of breeding values is higher, especially with regard to traits with a low heritability. • Shortening of the generation interval and an increase in the intensity of selection • Selection does not need to be gender-determined. • Good method for reducing hereditary defects
Contra	• Danger of a narrowing of the gene pool of the population and decreasing the variety of breeds • In order to take advantage of GS or MAS, the use of reproductive techniques (especially ET) is necessary. • Breeding structures are being redefined: because GS and MAS are usually conducted by breeding organizations, the danger exists that decisions on breeding will less often be made by those raising the animals. • The applied techniques are often patented, which means that their use might be restricted.
Consequences of Rejection	• Problem that in the future breeding companies will rarely make it known whether MAS was used on the bulls they offer or not, but they show genomic breeding values (which means that GS was used).

	• Breeding for functional traits can not profit from genome information, which slows the breeding progress down. • Reduction in the number of bulls available for organic breeding
Alternatives	• Traditional breeding practices
Evaluation	Tolerated, as long as provided that test designs can be developed that do not make an excessive use of a lot of undesirable reproductive techniques; in addition, issues related to patents and property rights need to be resolved

2.9 Hybrid Breeding

Hybrid breeding (not widely used for cattle)	
Description	The production of different homozygous, uniform lines (high degree of homozygoty), which are all very different from each other. These parentage lines are crossed with each other, so that the F-1 generation shows a high degree of heterosis (one example of this with a positive outcome is the SMR (a black and white dairy cow in the former East German Republic).
Pro	• The heterosis effect is especially noticeable with regard to fitness and fertility traits, which are important breeding categories for organic agriculture. • Breeding progress can be made quickly.
Contra	• The F-1 generation has to always be bred anew, because it does not make sense to use it for further breeding, since the F-2 generation usually experiences a drop in performance and a wide spread variation of traits. • Loss of genetic resources • Creates the necessity of having strict breeding procedures, which is usually only realisable by breeding organisations
Consequences of Rejection	• With regard to cattle breeding, rejection of this technique would not cause any major problems, granted that normal crossbreeding at farm level would still be permitted.
Alternatives	• Targeted breeding of thoroughbreds • Creating markets specifically for thoroughbreds, to compensate lower earnings with higher prices.
Evaluation	Tolerated, as long as it is used in the context of crossbreeding at farm level.

3. Conclusion

The discussions show that the use of reproductive breeding techniques is not unproblematic. With the exception of natural mating and artificial insemination, all of the techniques assessed above have been negatively evaluated, fully or partially.

Whether organic production regulations need further restrictions is a decision for the relevant authorities to make. In the case that new technologies are developed that are not dealt with here, but which have a connection to organic animal husbandry, they need to be taken up and discussed in a timely manner. The following is a list of aspects to consider in a discussion evaluating new techniques:

- Does the technique require systematic invasion of the animal?
- Will DNA-constructs beyond those from normal fertilization be introduced into the genetic make-up (gene transfer)?
- Will semen and egg cells be joined (fertilised) outside the animal?
- From the perspective of organic agriculture, how should techniques using genetic information but not gene transfer be evaluated (for example, GS or MAS)?
- Are there any issues related to property rights?
- Does the technique promote breeding goals that do not align with the basic principles of organic agriculture, or does it go against the mission and vision of general organic principles?
- Will a technologically determined selection opposed to the goals of organic agriculture take place?
- Will the variety in the gene pool be reduced through the use of this technique?

The results of this working group represent the first step toward a comprehensive discussion that should be continued among farmers, farmers organisations, and scientists.
For these reasons, it is crucial to recognize, by way of conclusion, that organic farming pursues breeding methods that differ from conventional methods, both with regard to goals and techniques, including the use of reproductive techniques. That is why the particular needs and demands of organic farming should be taken into account in the further development and introduction of breeding programs; that way, livestock and their genetic material, bred without the use of inacceptable breeding and reproductive techniques, will be available to organic farmers.

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