ASIRPA

Socio-economic analysis of the diversity of Impacts of Public Research for Agriculture

Control of Animal Reproduction in Small Ruminants

Seasonality - Photoperiod

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Context

Strategies for the control of reproduction implemented by farmers target the choice of the period and timing of parturition, the reduction of unproductive periods, optimization of the litter size and finally, the application of artificial insemination (AI) with all genetic and health benefits that it provides. Artificial insemination is an essential tool for genealogy controls and the implementation of breeding schemes. In small ruminants the use of AI on farm took some time due to technical difficulties and cost. Most sheep and goat breeds have a seasonal breeding period, during the second semester of the year when day length is decreasing. Complete cessation of ovulations and severe decrease of male sexual activity for about six months in spring and summer is the rule for most sheep and goat breeds in the Northern Hemisphere. In some farm animal species especially sheep, goats, horses and pigs (to a lesser extent), seasonality of reproduction lowers the rate of reproduction, induces a strong seasonal variation in product availability on the market, entrains important changes in the price paid to the producer, and provokes an annual discrepancy between production in farms and consumption by consumers. This discrepancy either provokes abrupt changes in consumer's habits (the products are available only 6 months over the year) or imposes to develop industrial techniques to store (essentially by freezing) the products, which is expensive and detrimental for quality.

The most common management of reproduction method in sheep and goat to alleviate this effect is based essentially on female hormonal treatments, using a sequenced treatment of steroid analogues and gonadotrophins extracted from pregnant mare serum (called "sponges and eCG/PMSG"). This allows an efficient out-of-season breeding and also an efficient use of artificial insemination (AI) in sheep and goat flocks, disseminating semen of improved sires on farm. Until the 90s, hormonal treatment associated with AI was the only method allowing an out-of-season reproduction (from March to August).

However, the evolution of European rules and directives goes towards a reduction, even an abrupt and complete cessation of use of exogenous hormones in females. Moreover, this is generally an expensive way for controlling out-of-season breeding, especially for meat sheep flocks, as it induces a rapid turnover of breeding females developing an immune response against exogenous hormones. Hormonal treatment also implies the use of the synthetic progestagen (fluorogestone acetate) used in vaginal sponges, for which a Maximum Residue Limit (MRL) is fixed by a European regulation (EEC 470/2009), leading to the discarding of one or two days of milk production when used in lactating goats.

In semen production centres where sires of high genetic value produce semen for AI, seasonality of rams and bucks sexual activity is also a major drawback because the lowest activity occurs exactly when the need for liquid semen to inseminate in farms is the highest (sheep) and because it imposes a 6-month complete stop of semen collection in the production process of deep-frozen semen (goats).
Thus, in female and male goats and sheep, there is a strong demand for non invasive, sustainable, cheap and efficient techniques to control out-of-season breeding.

Inputs and productive configuration

Seasonality of reproduction was identified as early as the fifties as being a major limitation for sheep, goat, horse and pig production.

During the 30 following years, the study of seasonality was essentially done mainly by the Animal Physiology division of INRA (research unit 'Physiology of Reproduction and Behaviors', and experimental unit 'Ferlus- fodder, environment and ruminants') but also the Animal Health division of INRA (research Unit SAGA: Animal Genetic Improvement Station). A small team within the neuroendocrinology group was created to (i) explore the neuroendocrine control of seasonality by photoperiod (*i.e.* daylength) and (ii) develop easy to use and on-farm applicable techniques to control sexual activity in both sexes.

The fundamental work was done by INRA PRC and SAGA, in collaboration with other international academic groups working in the same area (US universities, NIH, CNRS Strasbourg). Spanish and Tunisian academic partners also provided infrastructures. The applied research in farms and AI centers was done partly on the

experimental herd of INRA (Ferlus) and in collaboration with the industry, either with private pharmaceutical companies (Camco-Cambridge, then Sanofi, then CEVA) or French cooperative groups of farmers (Capri-IA, Institut de l'Elevage, Insemovin, etc).

The study of the male effect in goats was done with scientific partners working in latitudes where photoperiodic variations are of lesser amplitude and breeding systems are driven by small farmers with limited resources (CIRCA in Mexico, INIA in Spain, INRAT in Tunisia).

INRA teams initiated the first steps during 10 to 20 years following the 50s, which consisted in carefully describing the existence, or not, of a complete cessation of ovulatory activity in females maintained under good body condition during the year. It was thus clearly demonstrated that seasonality was a major problem in goats and sheep where all females of most Northern-European breeds completely stopped ovulating and showing oestrus behavior (« heat ») behavior during more than six months a year (the « anoestrus season »). This period, situated in spring and summer, exists in all flocks at the same time on the whole territory of Europe, provoking massive seasonal changes in small ruminant milk and meat availability.

It was therefore decided that small ruminants (goats, sheeps) were species in which it was interesting to investigate regarding the photoperiodic control of their seasonal reproduction. This was done by two simultaneous approaches: (a) a sort of « top-down » approach starting from the eyes, to identify which mechanisms allow the translation of the duration of light per day (daylenghth or photoperiod) to synchronize sexual activity (b) a « bottom-up » approach starting from the gonads (ovary and testis) to link cessation of gonadal activity during some months of the year with the external environment.

After more than 30 years of intensive work within INRA laboratory and other research institutions on several models including Alpine goat, Creole goat, Mouflon, Barbarine sheep, Chios sheep, Ile de France sheep, Serres sheep, roe deer, equine, fish, and avian species, a large part of the mechanisms involved in the light control of reproduction is now understood, but the whole picture still remains to be determined and the two above approaches have not yet been connected. However, the knowledge generated has led to the development of techniques which are now widely used in farms and/or AI centers.

The top-down approach revealed that in the 3 domestic species horse, sheep and goat, the eyes were the only entrance point of light changes (this is not true in birds) and that the nervous message received by specific cells of the retina was conducted by a purely nervous circuitry to the pineal gland, located at the center of the brain. Thus the pineal gland transforms this nervous message into a hormonal signal by synthesizing and secreting only at night, melatonin hormone, which controls sexual activity. The major discovery of melatonin as the main intermediate between photoperiod changes and reproductive control was especially interesting because of its efficiency and its harmlessness that allows it to be used as a pharmaceutical exogenous drug.

This top-down approach has also allowed the description of the most effective parts of the daily light cycle for the control of seasonal reproduction and the optimal light sequence that needs to be used to control it : (i) light during a photosensitive window located about 16 hours after dawn is sufficient to induce perception of long days, in sheep and goats (ii) short days are stimulatory of sexual activity but are not able to maintain it permanently, (iii) long days are inhibitory of sexual activity and restore sensitivity to short days. These findings were sufficient to explore new practical ways of managing reproduction in farms.

This approach also led to an important discovery: in rams and bucks, a rapid alternation of long and short days (i.e. one month-one month) for more than 2 years, completely prevents the appearance of seasonality by a subtle perturbation of the negative effects of gonadal steroids on GnRH neurons.

Research outputs

The research outputs are the know-how and methods developed thanks to the inputs described earlier, and the resulting good practices recommended to control the seasonality of reproduction.

Two protocols have been designed for semen production in AI centers, and two for reproduction out-of-season in farms. In addition to their simplicity, these methods provide an interesting alternative to classical

methods for controlling reproduction in the general context of reducing the use of hormones in animal production systems.

Protocols for rams and bucks semen production by AI centers:

The first protocol is dedicated to the full control of seasonality in rams and bucks in AI centers that seek a semen production all year round. This protocol overcomes the constraint of a period of sexual rest during the year. It consists of light treatments alternating for about one month of long days with about one month of short days, during the whole productive life of males and in light-proof buildings. This treatment is expensive because it requires light-proof buildings, and it is applied to high-value genetically selected males. It was improved to design light treatments which could easily be applied in AI centers. The last development steps were done directly in private centers of rams and bucks and are now widely used by them (all bucks from the French national scheme of genetic improvement are treated nowadays). This type of treatment allows bucks and rams to permanently show a high libido and a high semen production of good quality that can then be used either in liquid (rams) or deep-frozen (bucks) semen. These results, published in international scientific journals including French extension journals, were developed in conjunction with the industry.

The second protocol is dedicated to a partial control of rams sexual activity, for AI centers that produce fresh semen during the non-breeding season and, for some of them, can use freezing technologies to preserve semen. These centers require a 2-month period of high and good quality production during the heart of the anoestrus season, in spring and summer. The protocol can be applied in open barns, while animals continue to perceive the natural light and consists of about 2 months of extra-light long days provided by cheap bulbs automatically controlled, and mimicking long days, followed by either a return to natural light if early in the year, or a melatonin treatment (subcutaneous implant) when later in the year. This alternation long days-short days, induces about 1.5 months after the end of long days, a 2-month period of high libido and high semen production of good quality, generally used in rams within hours from collection to artificially inseminate hormonally-synchronized ewes.

Protocols for reproduction out-of-season in farms:

The third protocol is dedicated to on-farm control of out-of-season breeding in males and females and is, as far as we know, essentially used in goats. In this case the demand from farmers was either to have a constant milk production over the year to satisfy their customers (generally the case for « cheese-farms » products), or to have a partial or complete out-of-season production of milk to increase the income due to the high price of milk paid by the dairy industry during autumn and winter. It can be applied in open barns, while animals continue to perceive the natural light and consists of about 2 months of extra-light provided by cheap bulbs automatically controlled and mimicking long days, followed by either return in natural light if early in the year, or melatonin treatment (subcutaneous implant, see below) when later in the year. This alternation long days-short days, in association with the use of a « male effect **»** (sudden re-introduction of sexually active males inducing ovulations in females) with males treated by the second treatment above, provokes about 2 months after the end of long days, the resumption of sexual activity in females and a high fertility rate (≥75%) of females. Associating natural mating with light-treated bucks, this third treatment is widely used in goat farms in France; to our knowledge, this is used by nearly half of the farms that are registered for the official control of performances.

This treatment is also used in combination with the conventional synchronization by hormonal treatment, among farmers who practice out-of-season AI. Light treatments allow fertilization, by natural mating, of goats that remain empty after AI, due to ovarian activity maintained during 1 or 2 extra cycles after ovulation induced by the hormonal treatment (Pellicer-Rubio et al 2008). Moreover, a new synchronisation protocol based on vaginal sponge + male-effect was developed in goats in the objective of reducing the use of hormones (especially eCG which is extracted from another animal species), this protocol gives fertility results equivalent to that of the classical hormonal treatment (Pellicer-Rubio *et al.*, 2007 and 2008). It can be used only in advance of the breeding season if not coupled with light treatments. When coupled with light treatments (both male and females should be treated), it allows year-round reproduction with the advantage of using no eCG or prostaglandin. The use of this technique also permits to avoid that breeding females develop an immune response against eCG (this immune response which commonly appears beyond the 3rd hormonal treatment, leads to delayed or absent ovulation after hormonal synchronization) and thus increases their reproductive longevity. This protocol is currently used in farms located around INRA FERLUS which promotes the technique

among their farm network and accompanies breeders willing to start using it. This protocol has been described and disseminated in a technical sheet of the Goat Reproduction Group (see below) and is more and more advertised among the dairy goat sector as a first step towards hormone-free protocols. It is expected that the use of this protocol should spread in the coming years.
These 3 photoperiod day-light alternating protocols were never protected by any patent, but rather put directly into the public domain and implemented by the industry.

The fourth protocol consists in a melatonin treatment in late spring or early summer. It allows farmers to advance the breeding season of their ewes using a subcutaneous implant of melatonin which constantly releases melatonin over more than 3 months. The administration of a melatonin implant leads to an advance of about 1.5 months of the breeding season in ewes, which also produce about +20 to +70 lambs per 100 treated ewes compared to untreated ewes. This implant was registered in France and in Spain, before being also registered in many other countries. It is difficult to have data about the number of implants now sold in all countries, but it is probably more than 1 million implants per year in total, with about 140 000 in France (R. Touraine, CEVA Santé Animale, interview). The first generation of implants was patented by INRA, but not the second one for which a set of patents, originating from Australia, were bought at the beginning of the 90s by an English pharmaceutical company (Camco – Cambridge) then Sanofi, then CEVA and marketed during about 10 years as « Méthode INRA ». Marketing autorisation for melatonin implants has been obtained for use in ovine species in 1995. It is commercialized by CEVA under the name of Melovine® (FR/V/8657770 0/1995).

These outputs are based on scientific results, which have been published in international journals:

- Chemineau P, Pelletier J, Guérin Y, Colas G, Ravault JP, Touré G, Almeida G, Thimonier J, Ortavant R.1988. Photoperiodic and melatonin treatments for the control of seasonal reproduction in sheep and goats. *Reprod Nutr Dev*. 28(2B):409-22
- Delgadillo J.A., Leboeuf B., Chemineau P. 1991. Decrease of seasonality of sexual behaviour and sperm production in bucks by short photoperiodic cycles. *Theriogenology* 36(5), 755-770.
- Malpaux B, Thiéry JC, Chemineau P. 1999. Melatonin and the seasonal control of reproduction. *Reprod Nutr Dev.* 39 (3):355-66.
- Delgadillo J.A., Leboeuf B., Chemineau P. 1992. Abolition of seasonal variations in semen quality and maintenance of sperm fertilizing ability by short photoperiodic cycles in he-goats. *Small Ruminant Research* 9, 47-59.
- Pellicer-Rubio MT, Leboeuf B, Bernelas D, Forgerit Y, Pougnard JL, Bonné JL, Senty E, Chemineau P. 2007 . Highly synchronous and fertile reproductive activity induced by the male effect during deep anoestrus in lactating goats subjected to treatment with artificially long days followed by a natural photoperiod. *Anim Reprod Sci*. 98(3-4):241-58
- Pellicer-Rubio MT, Leboeuf B, Bernelas D, Forgerit Y, Pougnard JL, Bonné JL, Senty E, Breton S, Brun F, Chemineau P. 2008. High fertility using artificial insemination during deep anoestrus after induction and synchronisation of ovulatory activity by the "male effect" in lactating goats subjected to treatment with artificial long days and progestagens. *Anim Reprod Sci.* 109(1-4):172-88

Knowledge flow and intermediaries

In France, dissemination of technology and reproductive strategies for technicians and farmers in goat reproduction is ensured through the Goat Reproduction Group (Groupe Reproduction Caprine – GRC). This group was established in 1992, it brings together most of the stakeholders in the dairy goat sector. It is chaired by a representative of the National Federation of Goat Breeders (Fédération Nationale des Eleveurs de Chèvres - FNEC) that represents the goat herders and defends their interests in all matters relating to the goat sector. The GRC contributes to knowledge acquisition and know-how transfer through the redaction of « technical sheets » that provides information for actors in goat reproduction.

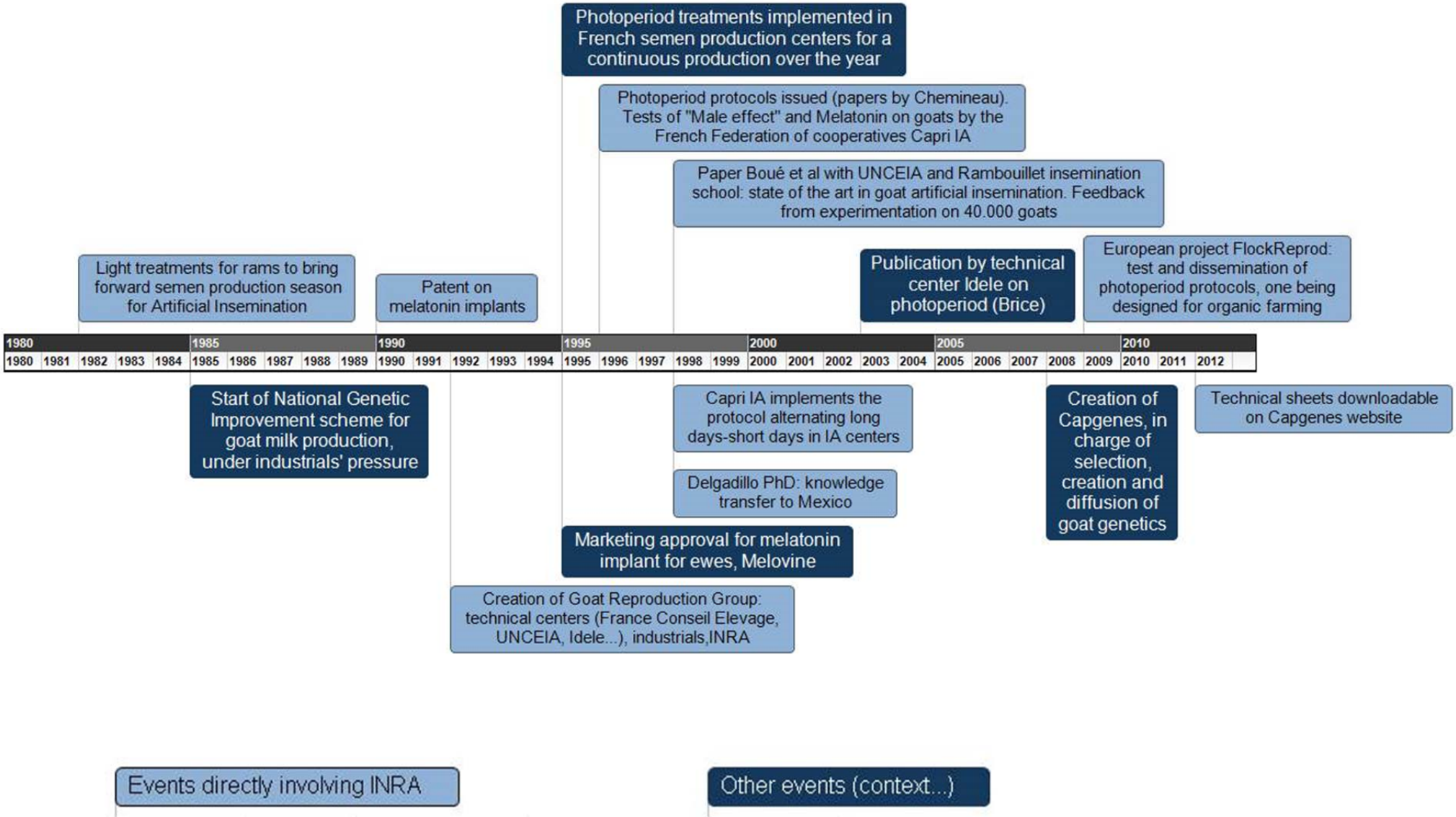
The technical committee of GRC involves representatives of:
- The French Livestock Institute (Institut de l'élevage- IDELE), which is a large structure of research and development in animal breeding, and has the mission to generate technical solutions to livestock farmers,
- The cooperative of semen production Capri-IA and the selection unit Caprigènes, now grouped in the structure Capgènes, involving 800 breeders, representatives of insemination and 13 cooperatives or groups of cooperatives. It has a major role in the diffusion of genetics,
- France Conseil Elevage (FCE) which is a structure for advising actors in all matters relating to the business of farming performance monitoring and the collection of new data,
- The Union Nationale des Coopératives d'Elevage et d'Insémination Animale (UNCEIA) which develops numerous collaborations with INRA and Idele in the fields of sperm production, supports to genetics selection programs and reproductive technology,
- INRA, scientists from the research units PRC, FERLUS (formerly SEIA), and SAGA.

INRA and Capgènes are linked by a Framework Agreement, which was signed initially in 1992 between Capri-IA and INRA-SEIA and renewed. In this agreement, experimental results from INRA are further assessed in voluntary private farms in a local network then, if validated, Capgènes is responsible for disseminating the technology to farmers or AI centers.

The R&D interface with stakeholders in ovine milk production is coordinated by the CNBL (National Dairy Committee Sheep). This committee brings together representatives of genetic, technical and professional instances of the three regions producing sheep's milk. Engineers and scientists from INRA and IDELE also participate in this committee. The CNBL also provides research and development in dairy sheep through five technical interface structures: breeding, reproduction (in common with ANIO - National Association in Ovine Insemination), food, technical support, mechanical automation and software in animal husbandry. ANIO and CNBL are enrolled in IDELE so that requests from breeders or industry are taken into account, translated into scientific questions that can be dealt with by INRA's scientists in appropriate collaborative research programs. The results are restituted to the actors by the same kind of interaction.
The technical institute IDELE also edits technical data sheets in ovine reproduction that contributes to the dissemination of R&D results.

A large dissemination of research and development results is also provided through the yearly meeting "Rencontres Recherches Ruminants" (3R). The "3R days" are co-organised since 1994 by INRA and IDELE. Their goal is to rapidly disseminate the results of recent research undertaken in different sectors of ruminant livestock and their products.

Chronology


Photoperiod treatments implemented in French semen production centers for a continuous production over the year
Photoperiod protocols issued (papers by Chemineau). Tests of "Male effect" and Melatonin on goats by the French Federation of cooperatives Capri IA
Paper Boué et al with UNCEIA and Rambouillet insemination school: state of the art in goat artificial insemination. Feedback from experimentation on 40.000 goats
Light treatments for rams to bring forward semen production season for Artificial Insemination
Patent on melatonin implants
Publication by technical center Idele on photoperiod (Brice)
European project FlockReprod: test and dissemination of photoperiod protocols, one being designed for organic farming
1980 1985 1990 1995 2000 2005 2010
1980 1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012
Start of National Genetic Improvement scheme for goat milk production, under industrials' pressure
Capri IA implements the protocol alternating long days-short days in IA centers
Creation of Capgenes, in charge of selection, creation and diffusion of goat genetics
Technical sheets downloadable on Capgenes website
Delgadillo PhD: knowledge transfer to Mexico
Marketing approval for melatonin implant for ewes, Melovine
Creation of Goat Reproduction Group: technical centers (France Conseil Elevage, UNCEIA, Idele...), industrials,INRA
Events directly involving INRA
Other events (context...)

Impacts 1

Economic impact:

In AI centers:

In AI centers seeking total control on ovine and caprine semen production, there is a complete appropriation of the technology.

Initially developed in sheep AI centers, the protocol involving rapid alternation of long days and short days in light-proof building is applied in barns of the industry and is now widely used by them (all bucks and rams from the French national scheme of genetic improvement are treated nowadays). Since 1996, photoperiodic treatments are used for semen production in goats, after the demonstration in 1994 that 3200 doses could be collected during the life of a male under alternating long days-short days vs 1400 doses without treatment (see table 1). This protocol is used since 1998 in Capri IA - Capgènes.

Table 1: Production of goat semen with treatment alternating 60LD-60SD (Chemineau et al 1996)

	No photoperiodic treatment		Photoperiodic treatment 69 Long Days – 60 Short Days	
Nb of collection/week	2	4	2	4
Nb of doses/buck/year	253	1106	391 (+55%)	1556 (+41%)
Fertility (%)	62,5	69,5	69,5	61,2

The number of artificial insemination strongly increased in goats after photoperiodic treatments were released in 1994. Between 1985 and 1995, it increased by 13% while it increased by 44% between 1995 and 2008. In comparison, for ewes, for which photoperiod was used as early as 1982, the number of AI increased by 114% between 1985 and 1995 and only by 13% during 1995-2008. These figures support the hypothesis that the increased semen productivity of bucks allowed by photoperiodic treatments contributed to increase the practices of artificial insemination in France, thus contributing to the diffusion of genetic progress.
Capgènes produces in 2014 more than twice the required doses for French AI centers. Part of these excess doses are used for international trading. Each year, France sells doses of goat semen in more than 25 countries, thus contributing to the worldwide diffusion of genetic progress. The leading position occupied by the French goat selection scheme allows it to be very prominent at international level. Figures regarding changes in the fertility of doses obtained after photoperiodic treatment reveal quality gains awarded by these doses, which may also have boosted French industries' renown abroad.
But that increased semen production mostly contributed to increase the semen availability and choice among proven sires for insemination, thus through avoiding running out of stock of a champion sire semen.

Environmental and Health impacts of increased semen productivity in AI centers

A large part of the excess doses produced through photoperiodic treatments are stocked in biobanks. CAPGENES annually produces 150,000 to 180 000 doses of frozen semen insemination. When proven sires are published in the catalog, the semen of high genetic value is available immediately. This also ensures resilience against potential sanitarian crisis and contributes to conserve biodiversity.

Use of photoperiod protocols on female goat raised for milk/cheese production:

Research on photoperiod and seasonality led to the development of a simple, inexpensive (no need for light-proof building in the farm) and effective technology to enable goat farmers to greatly increase the fertility out of season (Pellicer-Rubio et al 2008). The primary interest of the male effect managed with photoperiod is its low cost coupled with the benefit of grouping the parturition period in the herd.

In the dairy goat sector, until the 90s, hormonal treatment associated with AI was the only method allowing an out of season reproduction (from March to July). At that time the fertility rate of goats inseminated after hormonal treatment was around 55% out of season, and 65% during the breeding season. Breeders were however not completely satisfied with the technique because the goats which were not pregnant after AI (around 40 %) would not cycle and express heat behaviour until several month, when the following sexual season would start. Thus, the dates of kidding in the herd were disorganised, leading to negative economic consequences.

These difficulties were overcome thanks to the photoperiodic treatment of females that was popularised with success among goat breeders in the 90s. The combination of a photoperiodic treatment, which brings females to the precise physiological status required to respond to the male effect, with a similar photoperiodic treatment for males that stimulates their libido and their semen production gives the best results in terms of global fertility. This because it restores cyclicity for 2 or 3 cycles after the oestrus induced by the hormonal treatment and the bucks can then serve the remaining goats (see table 2). If no photoperiodic treatments are used, fertility and prolificity are close to 0 with natural mating during the on-breeding season. Photoperiod allows cyclicity to be maintain after an induction either by male effect or by hormonal treatments. The current protocols using photoperiod in combination with hormonal treatments commonly lead to around 60% of fertilisation by AI and up to 95% if bucks are maintained in goat groups for natural mating during the next cycle.

Table 2 : An example of the effects on fertility, prolificity and period of birth of the association of hormones and photoperiod treatments on goats (78 goats in artificial long days since December, hormonal treatment and insemination on May 14th. From Brice 2003)

	Cycle induced by hormones only	Returns of cyclicity (natural mating) thanks to photoperiodic treatment	Hormones + photoperiodic treatment
Fertility %	65	85	95
Prolificity %	223	165	205
Date of birth	7/10 - 14/10	29/10 - 12/11	7/10 - 12/11

Photoperiodic treatments have been used in farms since 1995 and this usage regularly increased for 5 years until stabilising (source P Boué - Capgènes). In 2002 a survey by IDELE revealed that 27% of farms among the 1,995 surveyed were practicing photoperiodism (Brice 2003). Nowadays, 50% of the 1.800 farmers belonging to cooperatives associated in Capgènes (total number of breeders in France is about 4800) are using photoperiod treatments for reproduction for dairy goats, which represents about 200 000 goats over a total of 840 000 goats in France. We have no information for the rest of the goat population as it is very difficult to find reliable data for breeders outside this selection nucleus, furthermore if not registered for milk record. But it can be assumed that the technique is also used by a significant part of those breeders. At the moment the protocols are used in combination with hormonal treatments or for natural mating. The use of photoperiod alone (without hormones) needs more research to become robust and reliable. The application of artificial long days (LD) followed by natural days is the most widely used protocol (60% of farms that practice photoperiodic treatment). Artificial LD followed by melatonin as well as melatonin alone are also used.

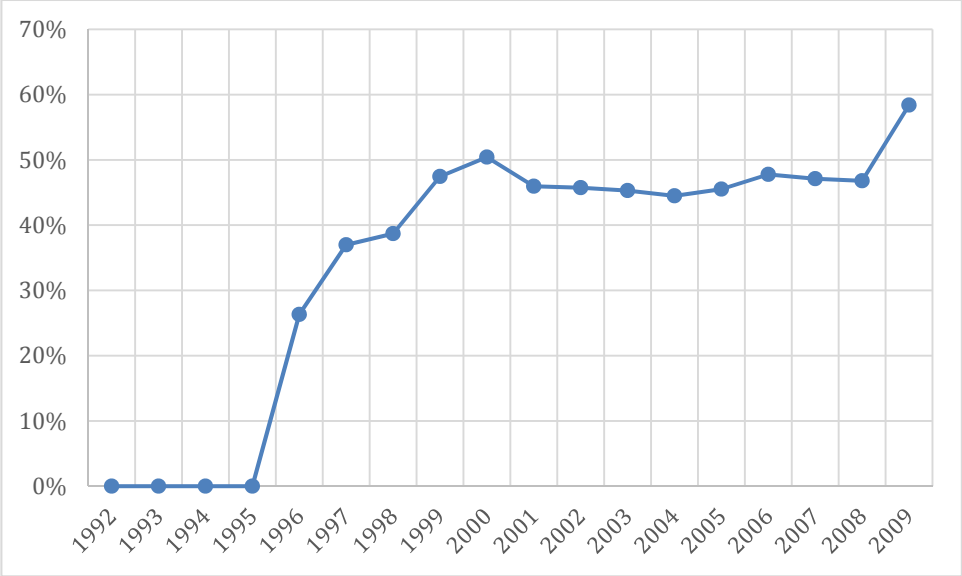
Table 3: Change in birth rate and milk production out-of-season in goat with implementation of photoperiodic treatments in 1994 (from Robert et al, 2000)

Campaign	93/94	94/95	95/96	96/97	97/98	98/99	99/00	00/01
Mean No of goats in the experimental herd	214	254	305	321	314	329	340	340
Average individual production (L)	529	534	668	680	745	745		
% Birth 3rd semester in the herd	9	63	87	85	92	86	93	88
% milk sold 3rd semester as compared to annual production	1	9	15	20	25	23	27	31
Average milk price (Francs/L)	2,81	3,18	3,5	3,59	3,43	3,51		
Average concentrate feed cost (Francs/kg)	1,59	1,38	1,28	1,36	1,35	1,11		
Gross margin / goat (Francs/goat/year)	1096	870	1722	1943	2113	2371		
Gross margin (Euros/goat/year)	167	132	262	296	322	361		
Average Gross Margin / goat (€/goat/year)	167	253						

Table 3 reveals that in experimental conditions, photoperiodic treatments contributed to a +75% of gross margin increase per goat, accounting for an 86€/goat/year gain. However, these results correspond to a small-scale study in well-controlled conditions. The gain is likely lower in real conditions.

The economic impact is more important in cheese producers where 2 or 3 groups of animals have to be in lactation at different periods throughout the year to ensure a regular production year-round. Moreover, since the Protected Designation of Origin (PDO), which stands for 12.4% of French goat milk collected (source CNAOL 2013), imposes the use of fresh milk in all seasons, goat cheese producers targeting the PDO label have to get fresh milk out of season. Commercial policies may be very incentive for producing all year round: for 2014, Terra Lacta, the cooperative involved in the business of wholesale of dairy products set a price of “out-of season” milk (September-October-November) 130€/ 1000 liters higher than in April-May-June (source Terra Lacta) (22% price increase as compared to milk bought 600€/1000 liters during the season). In farms performing out of season reproduction, most of the milk production is sold during this advantageous period. In that case, the benefit from milk of de-seasoned goat can be 50-60€ per goat per year as compared to “seasoned milk” (source P Boué, interview). Over the 38.000 goats treated with photoperiod in 2009 (source Furstoss 2014. See figure 1), which accounts for 58% of the total recorded French goat herd, that gain reaches 2.1M€/year for French farmers in 2009. Considering the 360 000 goats receiving photoperiodic treatment between 1996 and 2009, the cumulated gain could be estimated around 19.7M€.

Figure 1: Percentage of French goat herd treated with photoperiod since 1992 (after Furstoss 2014)



Use of melatonin implants on ewes raised for meat lambs:

The use of melatonin implants to advance the breeding season (June to August) is a technique also used in the meat sheep , however the protocols based on the application of artificial long days are still seldom used. It allows an increase by 20 to 70% of number of lambs born per year (Source: Chemineau et al 1996). With an average lamb weight of 14-18kg, a price paid to farmer around 6.5€/kg, an average prolificity of non-implanted ewe of 1.5 lambs/year, an increase of +20% to +70% of prolificity through photoperiodic treatments, the use of the technique should lead to an increase in incomes of 27 to 123€/ewe/year.

Impacts 2

Social impact: Photoperiodic treatment increasing the revenue of mexican underpriviledged farmers

Photoperiod treatment is adapted to economic and social characteristics of local breeding systems. In Mexico, goats are seasonal and about 90% animals are under extensive natural grazing conditions. In this system, males and females are together throughout the year. There is no control of reproduction or AI among farmers, the technology being too expensive. In 1992, José Alberto Delgadillo, a young researcher trained in the PRC laboratory of INRA, started to develop, at the University Antonio Narro in Mexico, the technique of the male effect using males rendered sexually active, during the sexual rest period (March-April), by exposure to artificial long days followed by natural photoperiod. The photo-stimulated males stimulate ovulations of goats kept indoor or in extensive management conditions in March and April, leading to parturitions between August and October. The economic value of the kids born during that period is increased by 150% as compared to kids born in the natural season of November-December. In addition, the farmers get 60 to 100% more milk during the first three months of production as compared to natural mating (June-September). JA Delgadillo created the Center for Research in Goat Reproduction (CIRCA) in 2004. With the participation of the researchers from the CIRCA and students in master and PhD in Reproduction at the University Antonio Narro, the technique was gradually spread. There are now 70 photo-stimulated males that are sent toward more than 250 farms to induce cycling and fertilisation of goats during the non-breeding period. This period is favourable to produce and sell milk to make cheese and “Cajetas”, a special “sweet” from Mexico. CIRCA continues its research to improve the results of the male effect, expecting to amplify its use among farmers (locally 3000-4000) that are part of an underprivileged population.

Potential impacts

Adoption of Artificial Insemination in Organic Farming:

In 1991, in the context of EU farm policy reform, the European Council of Agricultural Ministers adopted rules (Regulation (EEC) No 2092/91) on Organic Farming and the labelling of organic farm produce and foods. Initially it covered only plant products, but further rules on animal products were introduced later, prohibiting the use of hormones or similar substances to control reproduction (e.g. induction or synchronisation of oestrus), or for other purposes. Then in 2007 the European Council of Agricultural Ministers agreed on a new Council Regulation (Council Regulation (EC) No. 834/2007) setting out the principles, aims and overarching rules of organic production and defining how organic products were to be labelled.

The European project Flock-Reprod « Hormone-free non-seasonal or seasonal goat reproduction for a sustainable European goat-milk market » was implemented by a consortium of 5 Small and Medium Enterprise Associations (SMEA), 3 SME and 7 Research and Technology Development performers from 7 different countries : Croatia, France, Greece, Italy, Portugal, Romania and Spain.

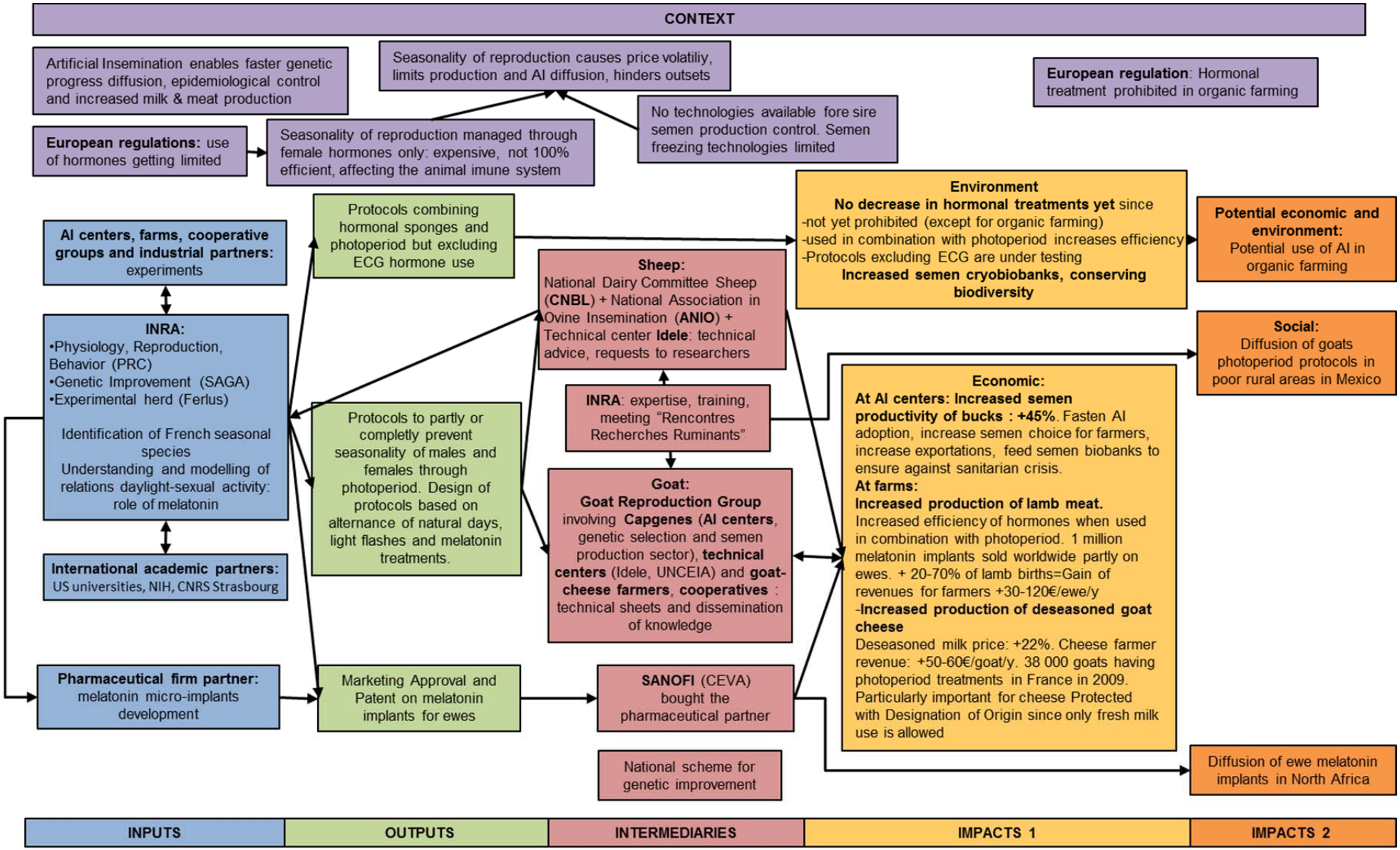
It proposed alternative techniques to hormonal treatments in small ruminants reproduction, adaptation of these techniques for AI implementation, and to prepare the future of goat and sheep reproduction in Europe. 210 copies of a guide and a video on DVD were edited, a copyright has been deposited. FLOCK-REPROD® is now an EU-registered trademark recognised as a healthy and safe option for goat reproduction. The objective is to transfer the hormone-free methods (hormone-free AI protocols, light treatments without melatonin) to farmers enabling them to produce hormone-free goat milk throughout the year. This would be a great benefit for goat breeders in the case of a total prohibition on the use of hormones in animal production. Moreover, hormone-free FLOCK-REPROD protocols can also enable EU breeders to convert to organic production (which has a higher added value) and to meet the growing needs of organic dairy products in Europe. This would help the goat dairy industry to fulfil the EC objectives for organic farming (CE 889/2008).

Environnement and health :

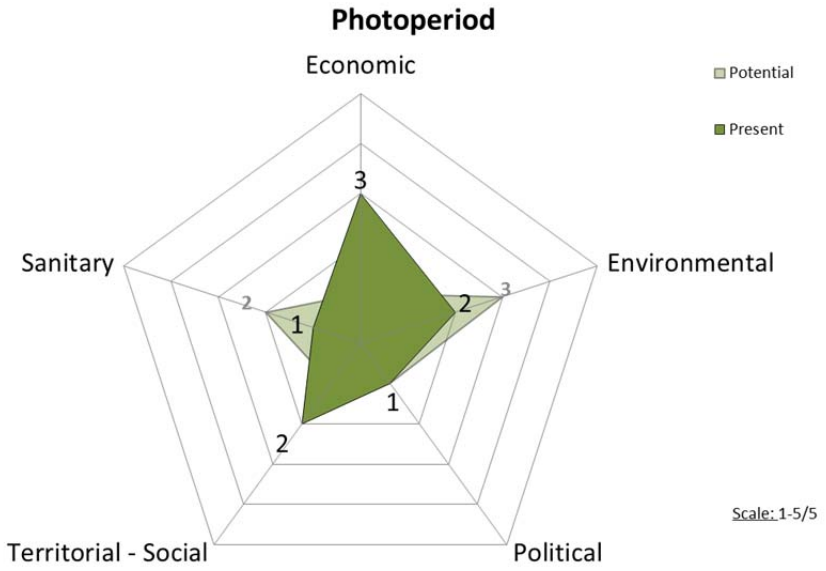
FLOCK-REPROD protocols will have a strong impact on food safety because they are either hormone-free or promoting the use of substances that are not subjected to maximum residue limits in milk and meat (such as prostaglandins or melatonin).

Regarding health concern, goat's milk is known to be easier to digest and less allergenic than cow's milk and to contain fewer calories and less cholesterol. Thus, the project results should help goat breeders to produce milk year-round in order to satisfy the market's growing demand for healthier products.

Impact Pathway



Vector of impacts



Impact dimension	Importance	
Economic	3/5	**AI centers: +45% semen doses/buck**. Allow more AI, more choices in semen catalogue, increased doses exportations. In farms: - **Increased production of meat lambs**. +20-70% lamb birth/y/ewe**=+27 to +123€/ewe/y** revenue - **Increased production of deseasoned goat-cheese:** De-seasoned goat milk price=+22% in 2014**=+50-60€/goat/y** revenue. Incomes for farmers: 38 000 goats photo-treated in France in 2009 = +2,1M€. Cumul France 1996-2009=+20M€
Environmental	2/5 Potentially 3/5	Increased sire buck productivity: semen biobanks created and fed allow conservation of biodiversity and secures against sanitarian crisis Potential decrease in hormone use (lower residues). Potential diffusion of Artificial Insemination in Organic Farming=> potential development of Organic Farming
Sanitary	1/5 Potentially 2/5	Potential decrease in hormone uses: less harmful to animal immune systems, less risks of toxicity for human consumption. Increase in goat milk offer, easier to digest and less allergenic
Territorial-Social	2/5	Photoperiodic treatment increasing the revenue of mexican underpriviledged farmers. Photoperiod treatment is adapted to economic and social characteristics of local breeding systems.

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