Applications of Mechatronics to Animal Production

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Abstract

The concept of biosensors technology applied to animal production, mainly based on the miniaturized electronic mechanics (MEM) has being used since the mid 70s into several stages of production, such as feeding, detection of metabolic testing in animal husbandry, as well as to individual identification and monitoring, which is an important step towards tracking of actions and application of traceability of events and processes in the animal protein production chain. Last generation of such devices includes the real possibility of storing animal data as well as providing authentication protocols. The concept of specific management of a certain event rather then treating the herd/flock as a whole, likewise the precision farming, leads the precision animal production to re-evaluate losses and misdiagnosis by increasing the efficiency and accuracy and the use of precision techniques. The application of mechatronics in animal production is found through the use of biosensors and MEMs, improving data collection and allowing more precise decision making actions. This paper presents some examples of the use of this technology in specific areas related to animal production.

1. Introduction

The overall performance of animal production depends on the herd or flock management as well as the nutrition, sanity control and lodging facilities. The concept of this kind of production is directly related to the reduction of selected losses and process control. Each production segment is controlled for reaching optimization in the whole production system. The concepts of precision animal production may apply at farm level for the animal management, housing environmental control, disease and nutrition control, information and identification, and ultimately, the overall treaceability

In the last decade new technical tools have been introduced in animal production units/farms as support to decision making, especially for management, feeding strategies, animal health and fertility. Along with that, specific computerized systems were developed in order to elaborate the related variables and to provide the manager/farmer with opportune and appropriate tools and alert signals.

Average based models were the basis for the standard method in commercial animal production farms for monitoring most operation, and the forecasted values were compared to measured ones as well as to the next forecasted value, generating a predict average estimated value and, generally introducing an error, so called deviation. This has been applied for feeding system, reproduction practices as well as for predicting behavioral patterns.

With the advancement in microelectronics the possibilities of its use in animal production became feasible mainly for providing reduction of losses by better supporting decision making processes. Biosensor technology has great potential for improving animal welfare, health and production efficiency. The recent increasing incidence of diseases, such as bovine spongiform encephalopathy (BSE), tuberculosis, brucellosis, mastitis, and foot and mouth, has raised concern in the livestock industry and in society. Infectious diseases of livestock have major implications not only in animal welfare and production efficiency but also in human health, and food safety and quality.

According to Holroyd (2000), the future of animal protein commerce depends mainly on an industry reacting towards the following concepts: honesty, openness, detailed information available, traceability, assurance of quality, and flexibility for changes. For the retailer or fast food buyer, it is only possible to build up a business when quality is always renewed, when final design is correct, and it is always available in the right place at the right time. Electronic traceability will enhance efficiency and accuracy in warranting safety in the animal's products chain.

This paper reviews the state of art as well as the prospective possibilities of the use of mechatronics in animal protein production systems.

2. Overall view on the possibilities of precision animal production

Currently, diseases are controlled mainly with vaccines and drugs but the emergence of antibiotic-and drug-resistant pathogens means that diseases will continue to be a problem. Moreover, the use of antibiotics will become even more severely restricted in the future. Biosensor approaches are a promising tool to diagnose, and thereby aid in controlling animal disease in a more individual basis. These systems are inexpensive and reliable diagnostic tools that can be used by non-specialists. In addition, the test could be done at the animal's side providing immediate information about the status of a disease.

The widespread use of antibiotics and chemotherapeutics in animal husbandry (to control diseases and improve animal performance) has led to the occurrence of veterinary drug residues in foods of animal origin. Many countries have been introducing more restrictive food control measures but traditional microbial methods are not sensitive enough to meet new regulations and classical analytical techniques are often precluded owing to the level of experience, skills and cost required. Biosensor technology offers an alternative drug-screening method that is highly sensitive, does not require sample preparation, and can be rapidly carried out on-line at a low cost. Biosensors could also be used in the detection of metabolic levels in veterinary testing and animal husbandry, for example estrus detection by monitoring progesterone levels in milk

By the mid-1970s experiments had been carried out with electronic transponders for individual feeding of cows and automatic data recording (Rossing, 1976 and Rossing 1978). The electronic "black boxes" (first generation) were attached to collars used around the neck. Later on, further miniaturization of electronics allowed the development of tiny electronic transponders, which could be injected under the skin (second generation). Also the price declined dramatically. Because of the many logistical and tactical benefits of electronic animal identification, a worldwide market could arise for this application, primarily for agricultural animals, but also for companion and zoo animals. This needed the standardization of codes and interrogation techniques. For this purpose, IOS came up in 1996 with two standards: ISO 11874 for the 64-bit code structure and ISO/11785 for the combined FDX/HDX interrogation protocol, working at 134.2 kHz (Eradus, 1993, Eradus, 1998 and Eradus and Janssen, 1999). The third generation, currently under development, includes also read/write possibilities for storage of the (medical/genetics) history of the animal and sensor technologies for automatic monitoring of animal health and performance. Moreover, advanced third generation transponders can also be provided with authentication protocols to prevent fraudulent copying of transponder codes. IOS is also developing a standard for this new generation, which will be compatible with the existing standards

It is understood as precision farming the use of special techniques and tools that permits specific management for a certain specific site and/or specific situation on field occurrence. The use of such techniques and/or tools is supposed to lead management to a certain specific decision, and more precise action, rather than the use of average based values decision. Likewise in animal production large herds or flocks incorporate losses due to management decision based on average values. As an example, literature states that the upper critical housing temperature (UCT) for raising poultry breeders is around 28°C, however when studying individual animals it is found that UCT can vary from 27 to 32°C in the same genetics, and in some individuals the fluctuation within this range can cause losses up to 4% in the final result of fertile eggs. Apparently geneticists could detect through molecular genetics and genome tracing, a genetic marker responsible for this fluctuation in environmental response, leading the genetic development of breeders in a direction of a specific selection of thermal resistant animals and consequently, making the flocks more homogeneous, reducing losses related to heat stress exposure.

The use of electronic olfactometry is another example. Electronic olfactometry mimics the human smelling system by using an array of gas sensors and a simulated "brain", transforming the organic compounds contained in the headspace of the sample into an electrical signal in the form of curves via chemical sensors (metal oxides). Currently, the combined use of an array of gas sensors and neural networks approach provides a rapid method for measuring smells and a complement to the human nose in smelling analysis. In this sense, quality control in the food industry is one application that has seen the strongest development in recent years. Gonzalez-Martin et al (1999) studied the differentiation of products derived from Iberian breed of swine by the use of olfactometry for classifying products on the basis of the diet they have received using adipose tissue as samples. The occurrence of fraudulent practices, consisting of the use of greased feed in an attempt to imitate the characteristics of range-diet animals, means that new methods are required to characterize these animals on the basis of their diet. Characterization of the aroma of Iberian breed products has mainly focused on cured products, using extraction with solvents, static or dynamic headspace, on solid adsorbents by gas chromatography coupled to "sniffing", or extraction with supercritical fluids. In this sense, relationships have been reported between the diet, genetics and sensory characteristics. The authors developed an algorithm that uses the electronic nose for identifying and classifying the specific meat product with precision. Olfactometry can be used as well to identify hazardous gases inside animal housing.

3. Applications

- **Biosensors**

Most biosensor developments have been in the biomedical field, where many in vivo applications demand small sizes. Claycomb and Delviche (1998) found that the on-line nature of a milk progesterone sensor did not require that the sensor be miniaturized to the point of utilizing microfabrication technology. Their primary considerations were the physical sensor design, fluid transport, optical sensor configuration, fluid mixing, sampling of the raw milk, and automation. The ideal biosensor would be a probe, similar to that found in a pH meter. Since the standard enzyme immunoassay identification of progesterone (EIA) is currently performed and standardized using microtitre plates, they used this technique as a starting point. The biosensor was then developed using EIA for molecular recognition and consequence identification of estrus in milking cows.

Radio frequency identification (RFID) plays a key role in electronic monitoring systems, which are inherently related to sensing systems. This combination makes it easier to switch from intensive to semi extensive animal husbandry systems (e.g. group housing of sows) as cited in Geers et al (1997). Different systems are used as RFID as shown in Table 1. Integration of on-animal sensing devices opens possibilities for the automation of sophisticated tasks such as health monitoring and reproduction status (estrus, pregnancy) (Hurst et al, 1983 cited by Claycomb and Delviche, 1998). Some examples are transponders equipped with a temperature sensor, as presented by Nelson (1988), or in combination with activity tracking (Artman, 1999). The accuracy of these implanted temperature sensors is about 0.2°C. As in most cases not the absolute values, but just the relative changes contain the significant information, the resolution must also be specified, and because of the digital representation of the temperature measurement, it is necessary to provide the result with at least one decimal place.

Table 1. Systems for electronic animal identification process

Operating principle	**Information carrier**	**Process**	**Applications**
Optical	Shape	Touching	Fingerprinting, processing
	Shape and color	Image processing	Processing, iris recognition, identification
	Number code	Code recognition	Automatic identification

	Bar code	Scanner	Trade, ear marker
	Electronic with infrared transfer (active)	Transceiver	Identification
Electromechanical	Surface acoustic waves (passive)	Transceiver	Identification
Electronic	Transponder (active and passive)	Transceiver	Processing, logistic, identification

Adapted from Artman (1999)

Sensor-based transducers also have been developed for monitoring the body temperature, the electrical cardiogram (ECG)signal and the pH value (Ville et al, 1993). These sensors have been used to monitor stress on piglets during transportation. The sensors are both the strength and the weakness of the monitoring concept. Typical performance aspects are the selectivity, the accuracy/resolution and long-term stability. In particular sensors with selective bio-interfaces can cause stability problems. An example of this class of biosensors is the interface with the enzyme glucose oxidase (GOD) for glucose detection. Improvements have been achieved with immobilizing techniques (Puers ,1993 cited by Eradus and Janssen, 1999). Because the sensor circuitry of these advanced devices requires a more or less continuous energy supply, small (mostly Lithium based) batteries have to be integrated in the transponder. Despite the application of very low power electronics, the lifetime of such devices is limited. One improvement to extend this lifetime is dual powering by using an internal battery for measurement and storage of data together with external an external radiating power source for transmission of data to the reader. Another alternative is the use of an external radiating powering source for both the interrogation and the semi-permanent activation of the sensor circuitry, thus enabling unlimited use of the sensor/transponder (Eradus, 1999).

- **Accurate behavioral data for supporting optimal housing design**

The optimal design of animal housing requires meeting a large array of variables, specially when the welfare standards are faced. For instance ideal dry bulb temperature, which associated to relative humidity and black globe temperatures away from the thermoneutral zone may lead to undesirable environment and consequent losses in production.

The thermoneutral dry bulb temperature for breeders during the production stage lies between 22°C and 28°C. When the upper critical temperature (UCT) is reached, the latent heat lost by evaporation is highly affected by environmental relative humidity level.

The bird's UCT is influenced by the ventilation rate, the presence of cooling devices, and the temperature of drinking water. The bird’s thermal regulation process in response to heat stressing conditions uses extra energy, leading to loss in productivity. Broilers in the first three weeks are more sensible to sudden weather changes requiring a more isolated building. Optimum poultry production requires a housing environment that can offer well-distributed ventilation within especially for the last week bird’s requirements.

The season's characterization is related to solar declination, and the solar orientation of a building is then affected by the solar radiation flux intensity that reaches all the housing sides throughout the day. During the Winter at latitude of 40°S, for instance the North side of a building receives in average three times more solar radiation than the East and West sides. While during Summer the North and South receive together only half of the solar radiation that reaches the Eastern and Western sides. In lower latitudes, as the case of São Paulo State, by the Tropic of Capricorn those differences are more enhanced and, during some clear sky Winters the Northern side is highly affected in term of incident solar radiation.
The location of a poultry housing regarding solar orientation is then of importance. Depending on the time of the year some side of the building will have more incident direct solar radiation as well as the diffuse radiation according to the sun movement. This will influence directly the total heat load inside the building.

Using RFID Nääs et al (2000) recorded poultry breeder's behavior and related their behavior to the environment characteristics using telemetry in small-scale model housing in two different solar orientations. Six female breeders were used in the models and they all had a transponder implanted. Four readers were used to record their movement within the small-scale housing placed on: nest, drinker, feeder and wall. The environmental parameters measured were: dry, wet bulb and black globe temperatures. Data were compared and the breeder's behavioral pattern according to environmental characteristics was determined as seen in Figure 1.

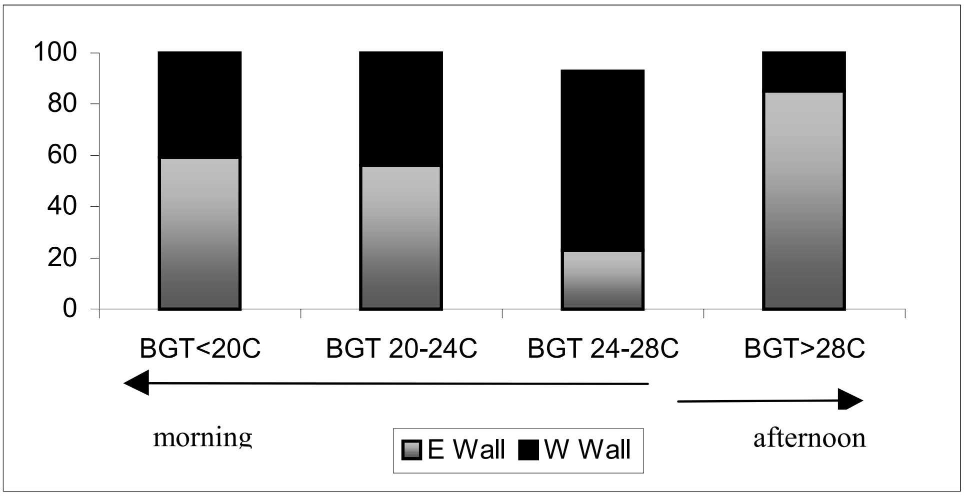

Figure 1. Percentage of placement considering the black globe temperature (BGT) data

Knowing in a more accurate way the behavior of animals by using RFID, it will be possible to design better housing for intensive animal production.

- **Use of transponders for ID in animal production and the use of treaceability processes**

Nevertheless consumers are quite aware of the health problems the ingestion of unsafe food may bring to them and their families and associate this item to the animals housing and management, ingestion of drugs and ultimately the process and conservation of the product throughout the market chain. Safety is one of the most demanded qualities in food products nowadays, and it interacts mainly for assuring quality. It is important to meet the consumer's requirements for food safety through the use of treaceability of the animal welfare and health control as well as the labor welfare and health, reducing also the risk of contamination from all sources in the process of production.

Devices for electronic animal identification, becoming available in the mid-1970s, facilitated the implementation of sophisticated livestock management schemes. The standardization by IOS of the next generation of injectable electronic transponders opened a worldwide market for all species of animals. The third generation, currently under development, includes also read/write possibilities and sensor technologies for automatic monitoring of animal health and performance. The addition of these sensors facilitates the automation of sophisticated tasks such as health and reproduction status monitoring

The discussion about the best place for implanting transponders in some species of animals is still being updated. Pandorfi et al (2002) and Silva et al (2002) presented solution for transponders applied in new born piglets inside the ear's base, for use in posterior traceability inside the whole swine production system. The use of transponders for complete electronic traceability in swine production remains a challenge. The use of electronic ear tags is still the most common way of tracking swine within the production sites.

Electronic identification of cattle usually referred to as RFID has many advantages for farm management. First, it can be regarded as a considerable improvement in relation to visual identification of numbers. The main advantages are the elimination of labor costs and the decrease of incorrect readings from 6% to 0.1% (Artman, 1999). RFID also facilitates the use of automated housing systems and combines the advantages of the conventional loose housing systems (relative freedom for the animals, attending some animal welfare demands) with the advantages of the stanchion barns (control of single animals). Allowing the automation of, for example, feed monitoring and rationing, weighing and drafting can implement sophisticated livestock management schemes.

Using RFID cattle management can be carried out on basis of the individual animal performance recording (as suggested in Figure 2), dispensing of feed, geographic routing dependent on the animal status. Examples are robot milking and the implementation of geographic information systems to assess the potential transmission of infectious diseases between herds (Geers et al, 1997). Also from the point of view of return on investment, RFID systems seem to be a good solution. Other important applications enabled by injected electronic transponders are improvement of disease control and eradication as well as fraud control. The latter application is very important within the European Union (EU), where premiums are being paid to stimulate extensive sheep and beef production. Also within the EU, it is not longer allowed to eradicate some contagious diseases by means of vaccination. In case of an outbreak, it is very important to trace back the origin, movements and contacts between animals to be able to stop the further dissemination of contagious diseases.

In practice, RFID implementations can give rise to several problems. Reading speed and distance must be optimized for specific applications. The International Committee for Animal Recording (ICAR) developed in 1995 a set of requirements regarding (among others) the reading distance and reading speed. Other issues include biocompatibility of encapsulation, as well as the injection site in connection with migration problem, recovery in slaughterhouses, and the open trade that needs standardization, and proper effective management of issued unique life-numbers.

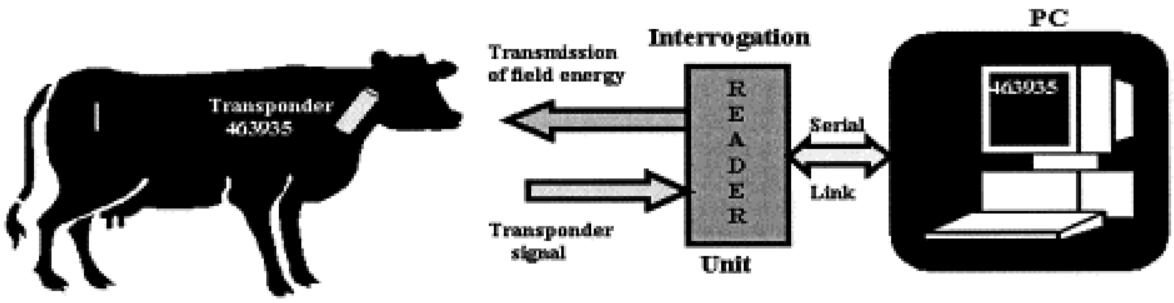

Figure 2. Data tracking/registering system overview in animal production (Eradus, 1999).

Due to the consumers demand on requiring certain characteristics of the product including those related to sanity control up to ecological features, identifying the final product is one of the objectives on the treaceability process. The treaceability in this case is to assure the consumer herd or flock welfare and health, good nutrition, non use of certain drugs and that there is adopted in the farm environmentally safe waste management.

- **Detection of estrus in dairy cows**

In many countries breeding results are declining as can be illustrated by a decrease in conception rates after artificial insemination and by an increase in calving intervals. Part of these problems seems to be related to the failure to detect estrus or to the misdiagnosis. It is generally accepted that heat detection efficiency is lower than 50% in most dairy herds (and, considering progesterone concentration in milk or plasma on the day of service, from 5 to 30% of the cows were not in or near estrus when inseminated (Appleyard, 1976; Hoffmann, 1976 and Nebel et al, 2000).

Continuous or almost continuous observations studies have shown that displays of estrous behavior occur unevenly throughout each 24 h period and many of them are of short duration (Esslemont et al, 1980). These findings were recently confirmed on large number of animals using electronic devices that allow continuous monitoring of behavioral activity. Therefore regular periods of observation of estrus are required which is less and less possible within the constraints of actual management practice, particularly because individual dairy herds increasing in size, the manpower input per cow will decrease. Figure 2 shows the percentage of accuracy in the estrus detection rate of milking cows, using two systems of observations.

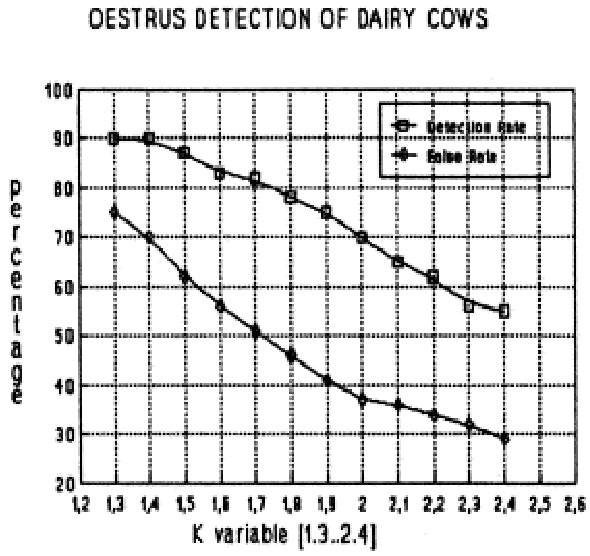

Figure 2. Percentage of accuracy in estrus detection of milking cows (adapted from Claycomb and Delviche, 1998).

Tested by Saumande (2002), the DEC® system (IMV Technologies, France) is an electronic device designed to detect estrus in the bovine species. Its principle is based on the electronic detection of standing mounts accepted by cows in estrus. The criteria (number of, length and interval between mounts) are analyzed by a microprocessor associated with the sensor and give a definition of the onset of estrus. During the course of this experiment, the efficiency of estrus detection by visual observation (69.8%) was higher than the efficiency usually reported in the literature (38 to 56%); however these values are averages and efficiencies over 60% have been already observed in individual herds. The continuous (24 h a day) surveillance of the cows represents one of the main advantages of electronic devices when detecting estrus. Therefore it looks surprising that the efficiency of the DEC® system was approximately only 50% of the efficiency provided by visual observation. Their data were not in agreement with this statement as the false positives represented 12.8% of the estrus detected by the DEC® system versus only 7% of those detected by visual observation. In comparison with the accuracy reported for HeatWatch®, another electronic pressure-sensing system, the accuracy for the DEC® system (84.6%) seems to be lower than the value of 100% reported by Xu et al (1998) but similar to the 85% observed Stevenson et al (1996).

Another way of detecting estrus in milking cows is the use of on-line system to automatically monitor luteal function by assay of each cow's milk for progesterone every time the milking machine was attached. Claycomb and Delviche (1998) present a sensor technology to implement the rapid assay and create an automated sensing system for operation in the dairy parlor during milking, and to evaluate the sensor performance and reusability for multiple test cycles. For an automated on-line sensing system, sampling of the raw milk stream was necessary. Although various sampling devices are commercially available to remove small volumes from a flow stream, a device was specifically designed for this biosensor. Since this mechanism is in contact with the milk being shipped commercially, cleanliness is of considerable importance. By using pinch valves, the milk never wetted the valves, and sample flushing by the next cow's milk was relatively quick and simple. Since flow through this valve was always inward, milk contamination was not a problem. The accumulated blocking effect of the milk proteins limited conjugate absorption to the fluidics components. The sensor was successfully developed to work on-line in a dairy parlor using a control computer for sequencing its operation.

- **Reduction of losses in animal production by the use of mechanized and electronic processes**

Individual electronic feeding has been used in dairy cows and grouped gestating sows breeders for nearly ten years. A transponder is placed in a necklace that opens automatically the gate and feeds individually each animal according to its milk production and need. The use of this technology has been developed mainly for large mammals (beef cattle, dairy cows and swine breeders) and is yet in development for broilers, specially breeders.
Processes such as milking of cows in the milking parlor are dependent on the control of the pressure in the pump, and the individual monitoring is important for identifying variables that may affect production.

In Nääs and Fialho (1998) is presented a system that uses a radio transmitter and a flux register inside an on-line milk production, pressure data can be measured and controlled, reducing the incidence of mastitis (due to pressure fluctuation) in the herd. Figure 3 a and b show the way the sensor measures and corrects the pressure in real time during milking.

Hogewerf et al, 1998 studied several methods of cleaning dairy cows prior to milking and found that the best way for this process was the mechanized use of water spraying with an electronic device that controls the amount of water sprayed as well as pulsing timing.

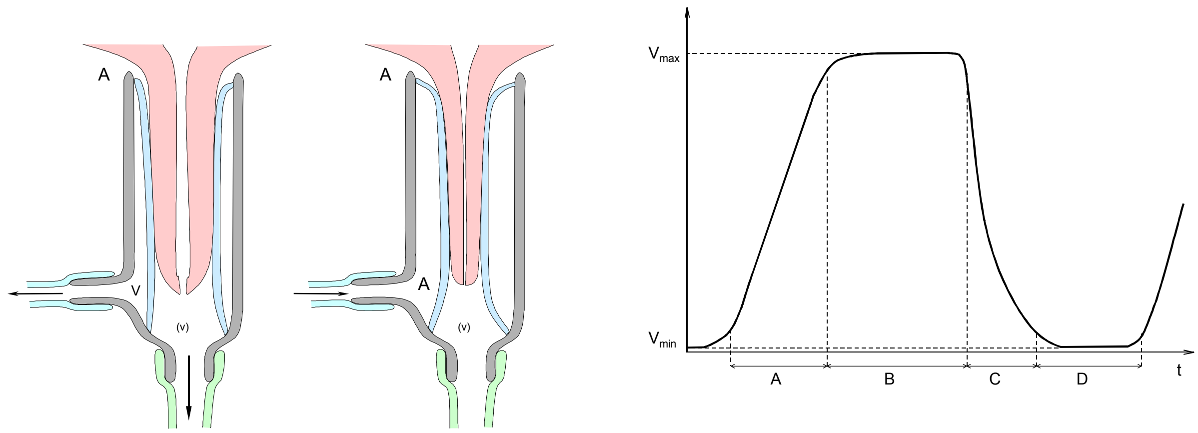

Figure 3 a. Pressure variation during milking

Figure 3 b. Readers and individual controlers

4. Conclusions

Biosensors show great potential for applications in the livestock industry, particularly where rapid, low cost, high sensitivity and specificity measurement in field situations is required, but the technology must overcome several obstacles before becoming a commercial success. The barriers for the slow transfer of technology from the lab to the field are mainly technical, particularly in the production methods to fabricate reliable and inexpensive sensors, in the stabilization and storage of biosensors and above all in the total integration of biosensor systems. The application of biosensors requires a specification that should include a sampling system, a biosensor, a calibration system and a model of how the information is to be used to control the process of interest.

More than 100 million dairy cattle, as well as sows, in the developed world are managed using artificial insemination and thus the potential for the progesterone biosensor system is tremendous even if only a small proportion of farmers take up this technology. The biosensor system will also be capable of being extended to disease monitoring, analyzing routinely for markers of mastitis infections or antigens of disease.

With the use of miniaturized electronic mechanism (MEM) will be possible to record and control, each time in a more accurate way, events or diseases in order to respond for the optimization of animal protein production.

The use of automation/mechatronic in animal production will help farmers decrease losses during the animal production cycle, by the use of precision principles and more accuracy, improving animal management.

The role of traceability in the animal protein production process remains a challenge for facing the consumer's demand, while practical solutions in the complete food chain are still missing. There is a large room for transfer of technology as well the development of new devices and applications of new techniques and systems.

5. References

Appleyard W.T. and B. Cook 1976. The detection of estrus in dairy cattle. Vet. Rec. (**99)** 253–256.

Artman, R. 1999. Electronic identification systems: state of art and their further development. Computers and Electronic in Agriculture (24) 5-26.

Claycomb, R. W. and Delviche, M. J. 1998. Biosensor for on-line measurement for bovine progesterone during milking. Biosensors & Bioelectronics (13) 1173-1180.

Eradus, W. J. 1993. The development of Standards for automatic animal identification. Proceedings of the XXV CIOSTA-CIGR V Congress. Wageningen, 1993, pp 307-311.

Eradus, W. J. 1998. Developments of electronic animal identification in Europe. Proceedings of the TAG Europe 98 Congress. Antwerp, 1998.

Eradus, W. J. and Janssen, M.B. 1999. Animal identification and monitoring. Computers and Electronics in Agriculture (24) 91-98.

Esslemont, R.J., R.G. Glencross, M.J. Bryan and G.S. Pope. 1980. A quantitative study of pre-ovulatory behaviour in cattle. Appl. Anim. Ethol. (**6**) 1–17.

Geers, R. Puers, B., Gedseels, V. Wouters, P. 1997. Electronic Identification. Monitoring and Tracking of Animals. CAB International. Wallingford.

Gonzalez-Martin, I. Perez-Pavon, J. L., Gonzalez-Perez, C. Hernandez-Mendez, J. Alvarez-Garcia, N. 2000. Differentiation of products derived from Iberian breed swine by electronic olfactometry (electronic nose). Analytic Chimica Acta (424) 279-287.

Hoffmann, B., Günzler, O., Hamburger R. and Schmidt W.. 1976. Milk progesterone as a parameter for fertility control in cattle; methodological approaches and present status of application in Germany. Br. Vet. J. (**132)** 469–476.

Hogewerf,P.H., J.V. Van Den Berg, Y.De Haas,A.H.Ipema, and J.Stefanowska. 1998. Teat Cleaning With Pulsating Liquid Streams: Cow Behavior And Milk Flow Rate. Fourth International Dairy Cows Conference. 1998, p1-8.

Holroyd, P. 2000. Tendências do mercado de carne para o novo milênio (Tendency of the meat market for the new milenium). Proceedings APINCO. Campinas. May 2000, p 93-109.

Nääs, I. A. and Fialho, F. B.. 1998.Zootecnia de precisão (Precision Animal Production). Organized by Silva, I. J. O. .Ambiência na produção de leite em clima quente. Piracicaba, 1998. (1) p1-9.

Nääs, I. A., Pereira D.F.,. Curto, F. P. F ,. Behrens F. H, Carvalho, J.C.C. , Amendola, M. and Mantovani E. C. Determining The Broiler Female Breeder Behavior Using Telemetry.The XIV MEMORIAL CIGR WORLD CONGRESS 2000, Tsukuba. Proceedings of The XIV Memorial CIGR World Congress. Tsukuba, Japão: CIGR, 2000. (1) p 1014-1018.

Nebel, R.L., M.G. Dransfield, S.M. Jobst and J.H. Bame. 2000. Automated electronic systems for the detection of oestrus and timing of AI in cattle. Anim. Reprod. Sci. **(60)** 713-718.

Nelson, R. E. 1988. Electronic identification in the United States. National Work Planning Meeting on Electronic Identification of Beef and Dairy Cattle. Ottawa, 1988.

Pandorfi, H., Moura, D. J., Silva, I. J. O., Sevegnani, K. B. and Caro, W. I. 2002. Evaluation of the migratory distance of passive transponder injected in piglets. In International Congress of the International Pig veterinary Society. July 2002. (1) 309.

Rossing, W. 1976. Cow identification for individual feeding or outside the milking parlor. Proceedings of the Symposium on Animal Identification Systems and their Applications. Wageningen, 1976.

Rossing, W. 1978. Automatic data recording for dairy herd management. Proceedings of the International Milking Machine Symposium. Lousville, 1978.

Saumande, J. 2002. Electronic Detection of Estrus in Postpartum Dairy Cows: Efficiency and accuracy of the DEC system. 2002 (article in press) Livestock Production System.2176.

Silva, K. O. Nääs, I. A. and Salgado, D. D. 2002. The ID microchip migration in piglets. In International Congress of the International Pig veterinary Society. July 2002. (2) 439.

Stevenson, J.S. , M.W. Smith, J.R. Jaeger, L.R. Corah and D.G. LeFever. 1996. Detection of estrus by visual observation and radiotelemetry in peripubertal, estrus-synchronized beef heifers. J. Anim. Sci. (**74**) 729–735.

Ville, H., Janssen, S. and Jourquim, J. 1993. Monitoring physiological parameters. Animal Monitoring and Identification. The European Systems Amies. Portugal, 1993, pp 63-79.

Xu , Z.Z., D.J. McKnight, R. Vishwanath, C.J. Pitt and L.J. Burton . 1998. Estrus detection using radiotelemetry or visual observation and tail painting for dairy cows on pasture. J. Dairy Sci. (**81)** 2890–2896.