Behavioral research and its application to livestock transport and policy: A European perspective

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ABSTRACT: The European farming industry has been concerned by the conditions of transport of animals for a long time. Initially, the main objective was to reduce mortality, bruising, and occurrences of low-quality meat. However, in some European countries, such as Great Britain, the public was also questioning farm animal welfare during transport. Large campaigns against poor treatment during transport have been launched in the media by animal-protection societies. One consequence of that public concern in Europe has been the adoption of several regulations by the European Commission.

The initial objective of scientific input was to help industry avoid the detrimental effect of transport. It dealt mostly with the physical conditions (duration, temperature, space allowance, and stability) during, before, and after transport. The effects of these conditions on the neuroendocrine system, especially on stress hormones, which have a direct impact on meat quality, have been specifically studied. Nowadays, animal welfare is a major concern of scientists. Animals are considered as sentient creatures; they should be protected against poor treatment and have the best possible welfare. The welfare status of an animal is a subjective notion that depends on the animal's emotional status. This emotional status depends on the way the animal evaluates its situation. This evaluation is influenced by previous experience and by genetic background. This article will report scientific work on the effects of the latter two factors on an animal's reactivity to transport and to other forms of stress. It will also discuss the relationship between animal welfare during transport and the quality of meat products. In the future, new ways to investigate animal welfare are likely to develop, such as the appraisal theory and possibly the use of methods allowing the analysis of brain activity.

Key Words: Animal Welfare, Behavior, Cattle, Pigs, Quails, Transport

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Introduction

In developed countries, the general public is increasingly concerned about the welfare of farm animals. This concern is not new: texts from Greek philosophers have dealt with the topic. It has been more recently addressed by several philosophers (see, e.g., Singer, 1977; Ferry, 1992; Chanteur, 1993). Whereas some people see animals only as economic objects, denying animals are sentient living creatures, others claim that animals have their own inherent rights. Most scientists believe that humans have at least the duty to avoid any unnecessary suffering of animals and that they must provide the environment necessary for the physiological and psychological developments observed when the animals are living without constraints (Fraser and Broom, 1990).

The interest in welfare issues has been boosted by animal protection societies. Their actions have been quite successful in the past and partly explain the high level of awareness of the public on these issues. A book by Ruth Harrison (1964), *Animal Machines: The New Factory Farming,* had a great impact on public awareness of farm-animal welfare. It is said that the subject most frequently addressed in mail sent to the European representatives is animal welfare. Of a representative sample of 1,000 French people, 85% were aware of animal-welfare problems, and 33% ranked the conditions of transport as the most important problem (Ouedraogo, 1998). In Europe, very active campaigns have been launched to vilify mistreatment during transport. The following text will first summarize the European regulations concerning animal transport and then will present some recent data demonstrating the psychological component of the welfare of animals during transport.

European Regulations

Two main organizations representative of the European countries are dealing with welfare regulations

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Table 1. Animal welfare during transport: regulations and scientific reports adopted by the European Union and recommendations adopted by the Council of Europe

Title	Directive (D) or regulation (R)
European regulations	
International transport of animals	D 77/489/CEE
International transport of animals	D 81/389/CEE
Protection of animals during transport	D 90/425/CEE
Protection of animals during transport	D 91/496 /CEE
Protection of animals during transport	D 91/628/CE
Protection of animals during transport	D 95/29/CE
Stops during long journeys of animals	R 1255/97
Protection of animals during transport	D 411/98
Protection of animals during transport	D 1999/575/CE
Council of Europe recommendations	
European convention for the protection of animals during international transport	ETS 65
Scientific reports of the European Community	
Transport of farm animals	VI/3404/92 - EN
Standards for the microclimate inside animal transport road vehicles	SANCO/B3/AW/R13/1999

(Fabre, 1995): the Council of Europe and the European Commission. Both try to base their conclusions and recommendations on scientific information, and, if possible, scientific reports are prepared by independent experts. For this purpose the European Commission has created scientific committees. One of those committees is dealing with animal health and animal welfare. The Council of Europe has adopted recommendations on animal welfare, particularly during international transport (Table 1). Those recommendations are not always translated into national regulations. The European Commission adopts directives that should be translated into regulations by the different countries of the European Union. Several documents dealing with the protection of animals during transport have been adopted since 1977 (Table 1). They can be found on their Web site: http://europa.eu.int/eur-lex/en/lif/reg/en_register_1540.html. In these documents several points are addressed, and specific attention is paid to long journeys of more than 8 h, from the loading of the first animal to the unloading of the last one. The main concerns of the regulations are as follows: 1) density of the animals: for each type of animal, space requirements are given; 2) design of the facilities (loading and unloading) and of the truck: in particular, the animals should be able to drink either during the whole journey (pigs) or during stops (cattle, sheep, and goats); animals of the latter group should also be allowed to eat during stops; the floor should be bedded; the temperature should range between 5 and 30°C inside vehicles naturally ventilated ±5°C depending on the outside temperature; 3) duration of the journey: maximum lengths of journeys without unloading are given (e.g., 19 h for unweaned animals, 24 h for pigs, 29 h for cattle); adult or subadult cattle and sheep should have a stop of 1 h after a 14-h drive and then the journey can resume for another 14 h; after that last period, animals should be unloaded for at least 24 h in specific resting areas before the journey starts again (Table 2); the resting areas should be licensed; 4) training of workers; and 5) all companies should have a license that can be withdrawn if they do not comply with the requirements. These constraints are quite heavy and put pressure on the industry. Their practicality is still under discussion. New documents that take new scientific knowledge into account will probably be necessary in the future.

The Scientific Subcommittee on Animal Welfare has adopted two scientific reports for the European Commission. The first one adopted in 1992 deals with all aspects of transport. It gives a lot of figures concerning maximum densities and design of trucks. The second report addressed only a specific point, the microclimatic environment within the truck. It was stated that the microenvironment depends not only on the technical devices of the truck but also on the climatic environment outside the truck and the way the truck drivers use their trucks. So, the experts have chosen to recommend a specific environment rather than specific equipment. It is further recommended that environmental conditions in the truck should be fulfilled both during transport and during stops. The last report can be found at the following Web site: http://europa.eu.int/comm/food/fs/sc/scah/outcome_en.html.

Studies on the Effect of Transport on Characteristics Related to Economic Returns

For quite a long time the main aim of scientists working on transport has been to reduce health problems of animals transported to other farms or the down-grading of the carcasses of animals transported to abattoirs. For slaughter animals, different measurements are used, including variables directly related to economic gain (rate of mortality, bruising and DFD or PSE meat). Blood or tissue samples (e.g., stress hormones, metabo-

Table 2. Maximum duration of transport of farm animals in trucks (Directive 95/29/CE)

Species	Transport (first part), h	Resting on board, h	Transport (second part), h	Resting out of the truck, h
Calves, lambs, piglets	9	1 (water and feed)	9	24
Pigs	24 (water)			24
Cattle and sheep	14	1 (water and feed)	14	24

lites, and immune functions) and behavioral measurements (e.g., time spent standing, fights, and slips) are also obtained in order to explain changes in economic returns.

Several key factors have been identified and their effects have been analyzed, including the duration of the journey (Colleu and Chevillon, 1999), densities (Tarrant et al., 1992), mixing animals from different rearing groups (Elridge et al., 1988; Tarrant, 1992; Fernandez et al., 1995), and microclimatic environment (i.e., temperature, hygrometry, and toxic gases). See the report of a scientific committee from the European Union, SANCO/B3/AW/R13/1999.

Different recommendations have been published to limit the negative impacts on economic gain. However, animal welfare was not the main concern of these recommendations. An example of the difference in perspective is the use of feed at the abattoirs: the objective is to increase the glycogen content of the muscle and consequently to reduce the incidence of defective carcasses, but this practice does not protect the animals from suffering from metabolic deprivation during transport.

Definition of Animal Welfare and Its Assessment

A large range of biological criteria is used to assess animal welfare. Three main categories can be defined: health, physiology, and behavior (Broom and Johnson, 1993; Broom, 1996; Veissier et al., 2000).

Health. The environment in which the animals are raised should not cause high mortality and morbidity. Any bodily harm or disease reduces the animal's welfare. In addition, poor environments may lower the ability to resist abiotic (e.g., decrease of bone strength) or biotic adverse effects (e.g., immunosuppression) (Dantzer and Mormède, 1994). Although reduced resistance to disease and mechanical injuries do not in themselves reduce welfare, they are often an indication of poor welfare because they are frequently caused by poor husbandry conditions.

Physiological Traits. Certain short-term situations, such as transport, may cause changes in levels of specific hormones (cortisol, catecholamines, and opioids). These changes are not, however, very situation-specific and not even necessarily related to aversive situations. For example, increases in cortisol levels in the blood are observed during any challenging event, in particular during copulation. Although chronic stress (related to housing conditions, for example) does not usually change basal hormone levels, it may change the regulation of physiological systems. Any alteration of the normal physiology is potentially harmful for the animals. For example, physiological changes may cause changes in production and reproduction. Low growth and reproductive problems can be indicative of difficult living conditions. However, too high a productivity can have detrimental effects on health and consequently may reduce animal welfare.

Behaviors. The animal's behavioral expression gives a lot of information for welfare analysis. It is the main way for the animal to express its consciousness/awareness of the environment and its feelings. Behavioral studies aim to understand an animal's mental representations that can be modified by the environment. Some environments give rise to the development or expression of behaviors that are at best maladaptive or at worst deleterious for the animal, such as stereotypic behavior and self-mutilation. However, like physiological changes, specific behaviors are not always clearly related to stressful situations. Usually it is necessary to make comparative analyses.

It is possible to compare activities of animals kept under restrictive conditions and of animals kept under free conditions to detect changes of the time budget and the appearance of abnormal activities (e.g., stereotypes, apathy, and aggressiveness). It is further possible to study the preference for any item in the environment (e.g., floor, space, and social partner). A preference may be determined by giving the animals a choice between various items or situations. The results should be interpreted carefully. First, the animal's choice is influenced by what it is used to; second, the animal's preferences are usually short-term preferences; and third, the preferred situation may be better than another one but is not necessarily "objectively" good (Dawkins, 1980).

Finally, the price the animal is ready to pay to obtain some resource, in terms of key presses or distance walked, can also be measured using operant conditioning techniques (Ladewig and Matthews, 1996). In these tests, it is important to choose an appropriate task for the situation. The task should be learned and performed easily by the animal, but its performance should demand some costly investment of time or energy. The task should be easily integrated into the behavioral sequence leading to the consummatory act (e.g., it is not useful to require a nest-building performance in

order to obtain a feeding reward), and the experimenter should be aware of the possible development of routinization of the behavior.

The different measures described above do not have the same sensitivity to various constraints. For example, absence of morbidity and mortality does not suffice to determine that the environment is good. It is disputable whether death is always detrimental for the animal's welfare, especially if suffering does not precede it. A main objective, at least in Europe, is to understand the way the animal perceives the situation. Two definitions of welfare take in account that concern: "The welfare of an animal is achieved when it is in harmony with its environment and with itself both physically and psychologically" (Lorz, 1973) and "The welfare of an animal is its state as regards its attempts to cope with its environment and its health and feelings are parts of this state" (Broom and Johnson, 1993).

These studies aim at understanding how the environment can modify the mental representations of the animals and their affective and emotional status. Such mental states are inferred from changes in behavioral and physiological traits.

The most sensitive tool to appreciate the animal's subjective emotional state is usually behavior. However, all described measures are indirect measures of the welfare of the animals in terms of suffering or pleasure. At present, new techniques are developing, such as pet-scanning techniques, that allow researchers to appreciate activity of specific brain structures (Kendrick, 1998). Such techniques may in the future help us to determine the role of brain structure in specific emotional states.

Effects of the Social Environment, Experience, and Genetics on Animal Welfare

Different examples will be reported to illustrate that the animal's emotional state is not simply related to the situation but also to the animal's appraisal of the situation. For example, during transport, animals have to deal with a lot of new features, some of which have clear physical effects (e.g., duration of the travel, ability to rest, and fights). Other features have an effect more through the appraisal of the situation. Examples presented deal with the role of the social environment, of previous experience, and of genetic background in the animal's appraisal. Experiments presented are not all conducted during transport, but they study the effects of environmental factors that may be encountered during transport.

Social Transmission in Particular Through Olfactory Cues

Most of our farm animals are social species. Isolated farm animals usually try to return to their social group. They also adapt less easily to new circumstances when alone, for example, the presence of peers facilitates learning processes in cattle (Boissy and Le Neindre, 1990). Cattle have also been shown to be sensitive to their peers' emotional state; thus, the facilitating effect of peers on learning is much greater if they are calm rather than stressed (Boissy et al., 1998). We have shown that, similar to in pigs (Vieuille-Thomas and Signoret, 1992), in cattle this perception may depend at least partly on the presence of alarm substances in the urine of stressed cattle. Thus, heifers show a longer latency to feed from a bucket from which emanates the odor of urine of a stressed, rather than a calm, conspecific. Similarly, they show a longer latency to explore an unfamiliar object sprayed with urine from a stressed rather than from a calm conspecific (Boissy et al., 1998). In a subsequent study, heifers were left for 5 min in a corridor in the middle of which an odor was blown at a very low rate (Terlouw et al., 1998). Different odors were used in a Latin square design: the odor of water, of urine from unstressed and of stressed conspecifics, of cattle blood from the abattoir, and of dog feces (i.e., odor of carnivore). Apart from the odor of water, all odors provoked a similar increase in sniffing the air compared to controls (no added odor). Only the odors of stressed conspecifics, of blood, and of dog feces provoked an increase in a behavior called "stretched locomotion" (head stretched forward, and animal walking slowly with hoofs hardly lifted from the floor). We hypothesized that sniffing the air may be the reaction to any biologically significant odor added to a familiar environment, whereas stretched locomotion may be the expression of increased vigilance or fear, caused by the presence of an odor potentially indicative of danger. In any case, these results indicate that cattle perceive and react to these odors and although at present it is not clear to what extent the presence of such odors may contribute to stress perceived at slaughter we would recommend reducing exposure to such odors as much as possible.

Effect of Previous Experience on the Reactivity of Animals

Three examples will illustrate the effect of previous experience on the reactivity of animals. The first example concerns the effect of handlers on the welfare and productivity of veal calves (Lensink, 2000). A survey was carried out on 20 selected veal calf units. In half of the units selected, the farmers had good contacts with the animals, whereas farmers from the other half had "ordinary" contacts. During loading and unloading, animals' behavior and heart rate were recorded. At slaughter, meat characteristics were measured. Calves with farmers with good contact needed less effort to be loaded than the other calves (0.45 vs 0.59, $P < 0.02$) and presented fewer traumatic incidents in the slaughterhouse such as a calf hitting a gate or another structure or a calf slipping or falling (0.79 vs 1.59, $P < 0.01$). These calves also had a lower heart rate than the other

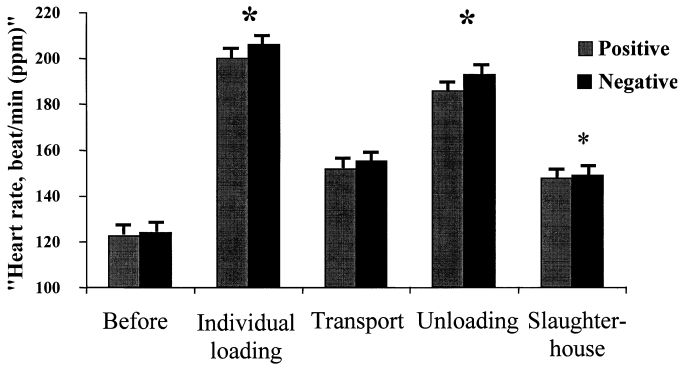

Figure 1. Influence of farmers' behavior on the heart rate of calves (Lensink, 2000) (*$P < 0.05$).

calves (Figure 1). Finally, fewer calves from "good" farmers had red meat (14.5 vs 23%, $P < 0.02$) and therefore were of higher value.

The second example concerns the effect of rearing treatment of suckling calves during early life on their subsequent reactions to handling (Boivin et al., 1998). Calves were reared during the first 3 mo of life outdoors with little human contact or indoors with frequent human contact. After 3 mo, calves were reared together. Eighteen months after the end of the housing treatment, calves were introduced into a crate, remaining isolated or in the presence of a human, and heart rate was measured. During the first minutes when the animals were isolated, their heart rates did not differ between housing treatments. In the presence of humans, whether the latter was passive or active, heifers reared outdoors had a higher heart rate than their counterparts reared indoors (Figure 2).

The third example concerns the effect of handling treatment of pigs during the fattening period or at the abattoir (D'Souza et al., 1998). During the rearing period, pigs were subjected to positive or negative handling treatments (**P** or **N**). At the abattoir they were handled in a usual or negative way (**U** or **N**). In that experiment, both handling treatments had an effect on meat-quality characteristics, but the treatment during the rearing period had a bigger effect than the one at the abattoir (glycogen 5 min after slaughter, mg/g: PU, 10; PN, 9.5; NU, 8.5; NN, 7.6; effect of on-farm treatment: $P < 0.002$; effect of abattoir handling treatment: $P < 0.067$).

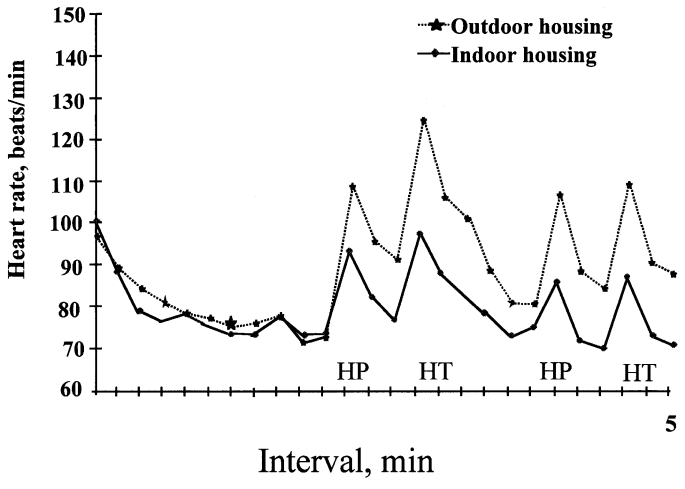

Figure 2. Influence of housing (indoor or outdoor) during the first 3 mo of age on the reaction to human contact (HP: human presence, HT: human touching) of 21-mo-old heifers: heart rate of the animals (Boivin et al., 1998) (*$P < 0.05$).

Effects of Genetic Variability

Reactions to handling vary greatly between cattle. Not only the cattle management but also their genetic background explains that variation (Le Neindre et al., 1995). Male and female calves from different sires were reared during the first 8 mo of their lives on different commercial farms. They were subsequently gathered at progeny testing farms. We tested their reactions to human exposure in a docility test. During the test, each animal was isolated from its peers and left alone for 30 s and then left with a human standing still for 30 s more. Subsequently the human tried to keep the animal in a corner of the pen for 30 s. The maximum duration of the test was 2.5 min. A score was calculated using different behaviors of the animals; 2,100 heifers and 4,000 bulls were observed. The results indicate a moderate value for the heritability of the docility score (best estimate of $h^2 = 0.22$) despite the heterogeneity of management on the different rearing farms (Sapa et al., 1997). The trait may be used for selecting the animals with higher docility in order to improve their welfare during handling procedures, including those associated with transport.

Various studies have shown that pigs of different breeds show different behavioral and physiological reactivity to stress (Hay and Mormède, 1998). Other studies have found that, in using a single slaughter procedure, different breeds show different meat qualities (McGloughlin et al., 1988; Enfält et al., 1997). In some cases, differences in physiological reactivity to stress explain much of the difference in meat quality. A well-known example is Piétrain pigs, which are generally homozygous carriers of the allele coding for a trait called "halothane sensitivity" or "malignant hyperthermia." These animals suffer from a metabolic abnormality: exposure to low or moderate stress levels causes excessive calcium secretion on the muscle cell level associated with a diminished capacity of the sarcoplasmic reticulum to fix calcium (Cheah and Cheah, 1978). Consequently, stress at slaughter may have very deleterious effects on meat quality in these animals (Eikelenboom et al., 1976). In most cases, however, the effects of stress on physiology cannot be explained by a single mechanism. Furthermore, differences in psychological or physiological stress reactivity are not always directly linked to differences in meat quality. Comparison of

Duroc and Large White pigs found that Durocs stand and walk for longer durations in a novel object test (10 min of habituation followed by 10 min in the presence of an unfamiliar traffic cone lowered from the ceiling) as well as during a human exposure test (10 min of habituation followed by 10 min in the presence of a human who quietly moved away from the animal each time the animal touched him). Even though Durocs did not touch the novel object more often than Large Whites, they touched the human significantly more often. Data have been corrected for the greater activity of the Durocs (Figure 3). The results show, therefore, that Durocs had a greater motivation to approach humans than Large Whites. In addition, for both breeds, heart rate was correlated with frequency of touching the human; Durocs had significantly higher heart rates. When the pigs were subsequently slaughtered at 100 kg using a "stressful" or a "nonstressful" slaughter method, the meat of the Large Whites was found to be more sensitive to slaughter methods than was the Duroc meat (Terlouw et al., 1997). Thus, the study showed that the greater activity and greater behavioral and physiological reactivity in certain situations of Durocs did not find their expression in perimortem muscle biochemical processes (Figure 4). It would seem, therefore, that breed-dependent physiological or metabolic characteristics of the muscle of Duroc pigs are such that their meat quality is relatively insensitive to the effects of stress. The results show also that good meat quality is not necessarily equated with low stress levels at slaughter.

Quail react to threatening events by a tonic immobility, and the duration of this response is a good indicator of the emotional reactivity of animals. Faure and his team have selected three lines of quails (long [**LTI**] and short [**STI**] tonic immobility and a control line) for more than 20 generations on that specific behavioral trait (Jones et al., 1994). They measured the meat quality of animals from animals at the 20th generation. Half of the animals were killed unstressed, and the other half were placed in a small box for 15 min before they were killed (Mills et al., 1997). The meat quality of the animals from the different lines when unstressed was the same. When stressed, LTI animals had a lower meat quality than STI animals (pH decrease in 24 h: stressed LTI, 0.7 and unstressed LTI, 0.9; stressed STI, 1.0 and unstressed STI, 1.0). Such results indicate that stress had no effect on the non-reactive animals (long tonic immobility animals) but had a significant effect on the emotive ones (short tonic immobility animals).

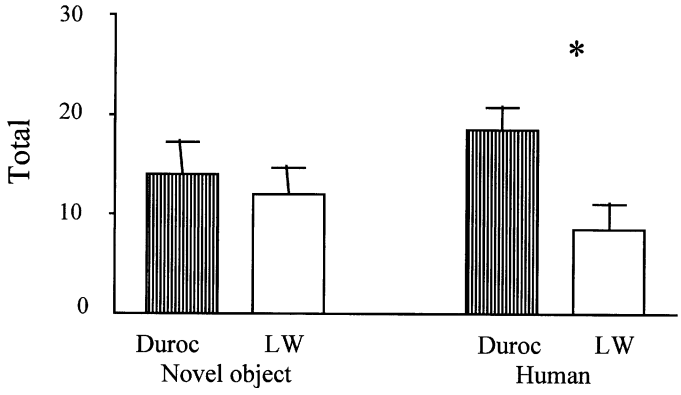

Figure 3. Total number of contacts with the novel object (left) and with the human (right) of Duroc (n = 21) and Large White (LW, n = 21) pigs (Terlouw et al., 1997) (*$P < 0.05$).

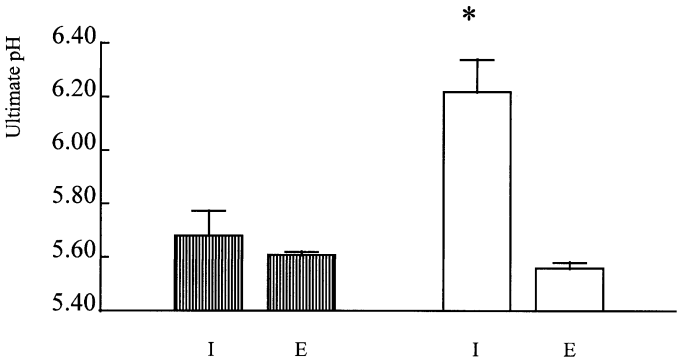

Figure 4. Ultimate pH of the adductor femoris muscle of Duroc (shaded bars) and Large White pigs (LW, n = 21; open bars) after slaughter in an industrial (I, stressful slaughter method, n = 18) or experimental abattoir (E, low stress slaughter method, n = 24) (Terlouw et al., 1997) (*$P < 0.05$).

Conclusions

Much scientific work has already been conducted to analyze the consequences of transport on animals. For a long time the work was mainly intended to decrease the negative consequences of the transport on the cost-effectiveness of the industry. At least in Europe, the public now asks for better transport conditions. The issue is a highly emotionally loaded subject that needs to be considered seriously.

The animal's welfare depends on the way it considers its situation. It is a subjective state, depending on the animal's emotional status that at present can be measured indirectly through different methods. The animals' appraisal of a situation is a complex process that involves not only the situation itself but also the experience of the animals and their genetic background, as illustrated by the different experiments reported in the text. The experiments further show that taking prior history and genetic background into account can help to improve animal welfare and also may help to optimize meat quality. The experimental approaches presented above are used increasingly often and will be necessary in the future to investigate better animal welfare. New methods such as techniques allowing the analysis of brain activity on farm animals should also be developed (Kendrick, 1998).

In the future it is likely that new regulations to improve animal welfare during transport will be published. The European industry will have to deal with those constraints by defining new techniques that will probably have a cost. The way those costs could be lowered to maintain their position in the world market is difficult to forecast.

Implications

We expect that new scientific information and increasingly sophisticated measuring techniques will help to formulate future regulations to improve animal welfare during transport. In particular, a better knowledge of how animals evaluate different situations, possibly using new neurological techniques, is necessary. The effect of new regulations on the meat industry should also be taken into account.

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