Review

Animal Welfare, Health and the Fight against Climate Change: One Solution for Global Objectives

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Abstract: Climate change is internationally recognized as a source of concern by governments, scientists and public opinion. In this context, the need to find concrete solutions becomes increasingly urgent. Numerous economic sectors contribute to alteration of climate, especially livestock and, more generally, food production-related activities. For this reason, animal welfare policies, the complex of norms and regulations adopted by single Member States and the European Union in the field of meat production, could be a useful instrument in the climate transition invoked by policy makers and scientists. The aim of this paper was to analyze the current system of animal welfare from a legal and veterinary perspective, and to demonstrate how important and useful, it could be in the fight against climate change; at least if correctly implemented and applied.

Keywords: animal welfare; health; antibiotics; climate change

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1. Introduction

In 1988, with the adoption of resolution 43/54 by the United Nations General Assembly, the international community stated its awareness that some human activities could affect the global climate. Since then, more than 30 years on, nothing has changed in terms of the effectiveness of international norms in countering climate change [1].

This international problem is becoming increasingly urgent considering the constant growth in the world population. According to the United Nations, this is set to reach about 8.6 billion in 2030 and 9.8 billion in 2050.

Population growth, urbanization, and increased incomes in developing countries are the main drivers of the higher demand for livestock products [2]. Indeed, the livestock sector requires significant amounts of natural resources and is responsible for about 14.5% of total anthropogenic greenhouse gas emissions [3]. Moreover, in intensive farming regimes, the use of drugs such as antimicrobials is widespread. Consequently, the application of a new, and more sustainable, method of farming becomes paramount. Animal welfare seems to be the best solution to help innovate the livestock sector and, above all, to safeguard human and animal health without neglecting environmental protection; any mitigation of emissions from livestock must be based on high animal welfare standards, so as to enhance the potential for reducing emissions [4]. The aim of this paper was to illustrate the current context of climate change and global warming law in the European Union (EU), in the farming sector. Furthermore, the authors intended to analyze how animal welfare could improve human health, via food production.

2. Climate Change and Farming: International Regulation and Perspective

The international legal standards adopted over the last 30 years to contrast climate change are mainly based on a number of different conventions. The first, adopted in 1992, is the United Nations Framework Convention on Climate Change (UNFCCC). It provides general principles on climate regulation and, above all, instituted the UN Conference of Parties (CoP) that serves as an international forum on climate policy. During the annual Conference meetings, two further legal instruments have been negotiated and adopted that make up the international legal framework on climate change: the Kyoto Protocol, in 1997, and then the 2015 Paris Agreement on Climate Change [1]. New livestock, part of a complex web of different activities related to the production of food of animal origin, is mainly regulated at national level. Each State applies its own norms, whereas the impact of farming in climate terms is global. It has become paramount to adopt a common method of farming which can facilitate a new, and more sustainable, approach towards animal use in food production.

Many international organizations are working on this objective, including the World Organization for Animal Health (OIE), the United Nations for Food and Agriculture Organization (FAO) and, at European level, the EU. Each one cites animal welfare as an indispensable method for modernizing livestock activities. The main difference between these organizations is the concrete impact of their activities. Unlike the EU, the OIE and FAO do not have binding powers, and can therefore only advise governments, promote studies and suggest guidelines, whereas the EU makes binding decisions in the field of agriculture, which includes livestock [5]. Indeed, Article 4 of the Treaty on the Functioning of the EU [6] states that the Organizations share power over agricultural regulations with Member States. The international climate law system is basically designed to reduce pollution. Animal livestock is one of the most polluting activities on Earth and Animal welfare policies are becoming increasingly crucial in the fight against carbon emissions [7].

Livestock Supply Chains: Impact on Animal Welfare and Environmental Sustainability

Through its Green Deal and Farm to Fork strategies, the EU has defined some specific objectives for the livestock sector, in particular reducing its environmental impact, improving animal welfare and reducing the use of veterinary drugs, with particular reference to antimicrobials. As part of the European Green Deal, the EU has set itself the key objective of achieving climate neutrality by 2050 [8]. This will require a significant reduction in current levels of greenhouse gas emissions over the coming decades. As an intermediate step towards climate neutrality, the EU has made a more ambitious climate pledge to reduce emissions by at least 55% by 2030 (Fit for 55 project). The new Common Agricultural Policy (CAP) itself, recalibrated, includes these issues and inserts them into a fundamental concept of One-Health, meaning that the health of the planet derives from an overall balance between human, animal, and plant health [8].

The fundamental role of agriculture and livestock is to meet the demand for food, and the recent COVID-19 pandemic has underlined how important it is to have a robust supply chain [9,10]. Furthermore, the income factor is central to businesses, which must be helped to become more efficient and competitive by guaranteeing that they can earn the income necessary to move forward and to adopt modern animal welfare policies, given that the global consumption of food of animal origin is on the rise [11], and is putting increasing pressure on ecosystems [12].

The 2009 Treaty of Lisbon explicitly recognizes that animals are sentient beings and that the EU and its Member States have an ethical responsibility to prevent mistreatment, pain and suffering [13]. This is the most significant response to the growing demand from European citizens to recognize animals' dignity, so as to distance animals from their historical legal position of being mere res [14].

This research field is an important opportunity for growth, with a view to continuous improvements in animal welfare, but also above all from an economic point of view, as it has now been established that where welfare improves, so too does the quality of produc-

tion [15]. Designing protected environments around the needs of species and improving management practices thanks to responsible action from all operators along the food chain [16,17] is all to the advantage of productivity, as it drastically reduces diseases, health interventions, use of drugs, mortality, and losses on farms and in slaughterhouses [18]. Equally important is winning over consumer confidence, as their choices are now increasingly rewarding producers who adopt virtuous and sustainable management models. Indeed, supply chain operators know that ensuring the welfare of animals is essential for good production and therefore for adequately remunerated efforts, so compliance with the regulations has to be a priority throughout the animals' lives, from breeding to fattening to the slaughterhouse, including transport.

Supply chains are tools capable of building value and transforming a territory at a social and economic level. They are vectors of innovation, in particular as regards sustainable practices in production, distribution and consumption. Whereas it is right to evaluate the impact that products of animal origin can have on the environment [19], on the other hand the modern concept of circular economy becomes key, in which waste is turned into a resource and a great opportunity for sustainable growth by reducing the consumption of natural resources and the development and implementation of technologies for material recycling and energy recovery. From cattle and pig farming, for example, not only are meat, milk and leather obtained, but also numerous other co-products destined for various sectors: from the feed sector through the proceeds of raw material to be used for pet food [20], to pharmaceuticals, with pericardial tissue being used for heart valves or gelatin used to make capsules for drugs [21]. Moreover, the cosmetic sector, in which fats are used for making soaps; the human food sector, which uses calf abomasum to extract enzymatic complexes for making natural rennet for cheese [22]; and last but not least agriculture, where rumen content and manure are used as raw materials to feed anaerobic digestion plants [23] from which digestate is obtained, to fertilize the soil or produce soil improvers [24], and biogas [25], which, if refined, becomes biomethane, with qualities similar to those of natural gas [26]. These substances are fed into the network and used for heating, cooking and automotive applications. The biogas obtained from farm waste can therefore be a precious ally of road transport and the energy sector in emancipating us from oil and in the fight against climate change, helping reduce carbon dioxide (CO₂) emissions as shown in a study carried out in the province of Cremona concerning the optimization of biogas production in one of the Italian areas most intensively dedicated to animal husbandry [27].

A further element pushing towards better animal welfare and which, at the same time, has a positive impact on the environment, concerns feeding animals a sustainable diet that includes the self-production of raw materials used in the rations and the reuse of former food products for human use, while still guaranteeing nutritional efficiency and at the same time high food safety. Self-production reduces the need to import raw materials and feed from territories that unconditionally exploit their natural resources, applying unsustainable practices such as deforestation; for example, almost all imported soybeans come from the Americas and, in some cases—in order to make room for agricultural land to be used for its cultivation—whole swathes of tropical forest have been eliminated, thus causing enormous damage to biodiversity and the environment in general [28]. By adopting a policy of self-sufficiency, we would increasingly move towards a process of so-called “carbon neutrality”, which needs to characterize the agricultural and animal production processes, as other production cycles [29], thus also helping to reduce the abandonment of farmland. Faced with this scenario, the agri-food sector is evolving rapidly, seeking to do everything possible to concretely respond to the requirements of increasingly demanding consumers, proposing certifications and traceability systems which offer purchasers all the information they need to understand the product's history in detail; examples include the Round Table on Responsible Soy Association (RTRS) certification concerning the soy supply chain, or the project of the Global Feed LCA Institute (GFLI) which was created to provide tools to support a correct assessment of the impact of feed production. Launched in 2015 in

the United States, the project is promoted by several international associations, including FEFAC, AFIA, ANAC and IFIF (i.e., the associations/federations of feed producers in Europe, America, Canada and the international federation), as well as by a plethora of national associations and international companies. Commission Regulation (EU) No 68/2013 of 16 January 2013 concerning the Catalogue of feed materials introduces the definition of former foodstuffs or ex-food, i.e., food products originally designed for human use compliant with the requirements of European regulations but which, for various reasons of an aesthetic or logistical nature, do not fall within the cycle of human nutrition and can be reused for the production of zootechnical feeds, identifying them as an opportunity in the zootechnical supply chains that are seeking to be defined as sustainable [30]. The new raw materials used are obtained from bakery products (bread, biscuits, rusks), confectionery products (chocolate, candies, snacks, etc.), products of cereal processing (puffed, extruded cereals, and cereal by-products) and dairy products. The sheer variety of ingredients and the high technology involved make it possible to prepare safe and sustainable food (simple and compound feeds) for animal husbandry [31]. Through a robust traceability system and constant product and process controls, reliable and specific formulations can be guaranteed for various types of animals, from poultry to swine to bovines (thus, for example, guaranteeing more stable ruminal fermentations and a greater appetite, a clear and unequivocal sign of good animal welfare), differentiating the composition to meet the specific needs of each phase of the animal's life. Proper nutrition translates into a more prudent use of veterinary drugs and less metabolic waste; reducing the number of unproductive animals lowers the production of climate-altering gases such as enteric methane (CH₄) [32], one of the best-known issues related to animal husbandry [33].

3. Animal Welfare as an Instrument for Evolution in Farming Activities

There have been many attempts to define animal welfare. According to the Farm Animal Welfare Committee (FAWC), welfare includes both physical and mental health and is determined by the skills of stockpeople, owners, and the farming system [34]. External factors, such as infectious disease epidemics, adverse weather conditions, global economics, and geo-political influences, can also impact animal welfare [34].

This growing interest in animal welfare, especially concerning husbandry and transport methods, has led to the possibility of using the claim “from certified herds” for herds that meet welfare requirements above the minimum standards established by law [35]. Thus, animal welfare would have an additional economic value, as it would offer consumers a product of higher quality and, at the same time, become an opportunity to increase farmers' income. However, some pain and distress are unavoidable in all animal sectors even with current knowledge, husbandry, and farming practices, although the goal should be to minimize their occurrence [34].

When assessing any welfare problem, consideration should be given to the extent of poor welfare, the intensity and duration of suffering, the number of animals involved, the alternatives available and the opportunities to promote well-being [34]. Moreover, animal welfare is pivotal to guaranteeing high hygiene, organoleptic standards, and production quality [18]. For this purpose, non-coercive and non-aggressive attitudes on the part of farm and slaughterhouse operators would be essential [16,17].

3.1. Indicators of Animal Welfare

Animal welfare is defined as a permanent state reflecting an animal's subjective perception of its situation indicated by behavioural, postural, and physiological parameters [36]. Although the issue of animal welfare has been a source of concern in the scientific community and of attempts to build common protocols over the last decades, many aspects are still under debate, such as the validity and reliability of the welfare indicators chosen [36].

An indicator can be defined as “a thing that indicates the state or level of something” [37]. A potential animal welfare indicator must include the following principles: validity (i.e., be meaningful for animal welfare), reliability (i.e., produce consistent results

when used by different observers) and feasibility (i.e., easy to use in the field) [38,39]. Resource- and management-based measures (RBMs and MBMs) are considered to be indirect indicators of animal welfare. On the other hand, direct indicators, or animal-based measures (ABMs), assess the animal's response to the resources available and to management practices [40]. The adoption of ABMs over non-ABMs is also encouraged by the European Food Safety Authority [41].

To evaluate an animal's welfare state accurately, it is thus essential to rely on multiple scientifically validated indicators, covering all the facets of welfare (behavioural, psychological, and physiological) and reflecting an individual's chronic state [42]. These indicators must be based on the characteristics and needs of the species and reflect the animal's perception [43]. Finally, when evaluating the welfare of a group of animals, the proportion of individuals presenting signals of poor welfare must be considered [44].

In Europe, the Welfare Quality[®] project [45] was one of the most important efforts for the development of on-farm welfare assessment protocols, using both AB and non-AB measures. The scores obtained are then organised to assess unit compliance with four main welfare principles (good feeding, good housing, good health, and appropriate behaviour). Finally, these scores are used to come to an overall evaluation.

There are two axes primarily involved in animal stress response: the sympathetic adrenal medullary system (SAM) and the hypothalamic-pituitary-adrenocortical axis (HPA) [46]. Activation of the sympathetic nervous system in emergencies involves the release of catecholamines (epinephrine and norepinephrine) from the adrenal medulla and of cortisol from the zona fasciculata of the adrenal cortex [47]. This mechanism is part of the endocrine response for self-protection of the body in the presence of a stressor [48].

Under normal physiological conditions, catecholamines are released from the adrenal medulla to maintain body homeostasis and to regulate several body functions including maintenance of blood pressure [49]. However, under stressful situations, high concentrations of catecholamines are discharged into the bloodstream in preparation for the possibility of rapid energy expenditure [49].

Cortisol plays a role in acute or chronic stress and is often called a stress hormone because its production increases during severe psychophysical stress conditions and therefore, it is an indicator of animal welfare [50]. Indeed, several studies have focused on measuring levels of cortisol or its metabolites in plasma, faeces, urine, saliva, and milk of different animal species [51,52]. Because salivary cortisol concentrations correlate well with cortisol concentrations in plasma [53], cortisol in saliva mirrors HPA axis activation. Plasma, salivary, faecal, and urine cortisol concentrations reflect acute stressors, but, unlike hair cortisol, they do not represent a long-term retrospective integrative stress response [54]. Indeed, hair cortisol concentrations can be used as a tool to assess chronic stress or long-term activity of the HPA but not for occasional and sporadic stress events [55].

The assessment of HPA axis activity has become a common approach to studying stress and animal welfare, along with measurements of other endpoints of the stress response [56]. Moreover, collecting blood at exsanguination is a common and non-invasive technique for assessing animals' physiological responses to the journey toward the slaughterhouse, to pre-slaughter handling as well as to slaughtering procedures. Indeed, among the parameters used as stress indicators, plasma cortisol is the most useful, showing a statistically significant variation [57,58].

3.2. Animal Welfare on the Farm

Animals are sentient beings capable of experiencing both positive and negative emotions [59]. The animal welfare concept incorporates many animal-based factors, including health, the absence of stress and pain, the ability to perform innate behaviours, and affective state [60]. However, it is important to clarify that the absence of negative welfare indicators does not necessarily suggest optimal conditions of animal welfare [61] just as good management and environmental resources do not necessarily result in a high standard of welfare [62].

In fact, environmental aspects may show high variation from country to country due to different housing and management conditions, while individuals with different genetic backgrounds (e.g., different breeds) may respond differently to the same environment [41]. For this reason, current welfare assessment protocols highlight the importance and preference for animal-based indicators over resource- or management-based indicators for on-farm assessments [63].

In addition to conventional animal behaviour measures, many animal welfare protocols include a Qualitative Behavioural Assessment (QBA), i.e., a methodology involving the assessment of the animal's response to its environment [59,64,65]. Indeed, farm animal welfare assessment approaches are focused on animal-centred concepts that include the animals' needs [66], affective states [67] and inter-individual differences [68].

It is extremely important to understand the behaviour of livestock to avoid exposing them to poor welfare conditions, such as those induced by stressful management practices. Livestock housing conditions are often structurally simple and offer limited possibilities to exhibit species-appropriate behaviour [69,70]. These limitations can lead to frustration and abnormal behaviour, which are related to stress and reduced welfare [71]. To decrease these phenomena in livestock, a variety of new structures, items and challenges related to the animals' needs and natural behaviour must be provided [69]. Some of these changes include: (i) the gradual removal of practices of restraint and confinement [72], (ii) the banning of many forms of manipulation and mutilation [73], (iii) more sensitive management procedures, and (iv) the growing use of environmental enrichment to allow a higher degree of behavioural diversity [74].

Several studies [75–77] show that consumers strongly associate farm animal welfare with outdoor access, adequate space requirements and the ability of animals to express their natural innate behaviour. Others frequently cited criteria concerning nutrition, water supply and naturalness of feed. Meuwissen et al. [78] found that citizens consider space, medicines and living surface as the most important indicators of the level of animal welfare. For this reason, one of the key goals of new EU-funded projects is to develop a concept that adequately considers society's definition of animal welfare [79].

In 2008, the EU Welfare Quality project re-elaborated the concept of the “Five Freedoms” of animals [80] and defined four main areas of animal needs (“Welfare Principles”), which were then split into twelve independent criteria, each of which corresponded to a key welfare question [81,82]. The welfare principles and criteria are: Good feeding; Good housing; Good health; Appropriate behaviour.

Animal welfare science is improving our understanding of animals' needs and preferences and our awareness that their well-being could be compromised by management and husbandry practices [83]. In fact, a condition of poor animal welfare can also be caused by poor management by the farmer. A late or wrong diagnosis of a specific pathology arising on the farm inevitably affects animal well-being. Late intervention, incorrect diagnosis, and inappropriate treatments may lead to poor health and suffering by patients, as shown in our work [84].

3.3. Animal Protection during Transport

Transport is always an essential and intrinsic part of livestock farming [34]. Today, animals are transported globally for the purposes of rearing, production, breeding, slaughter, or entertainment [34]. Live transport of cattle and sheep is increasing due to the growing demand for meat [85]. However, transport is a significant stressor for animals and frequently leads to severe behavioural and health problems [86,87]. Handling, loading/unloading, comingling, trailer accelerations and vibrations, exposure to new environments, and extreme temperatures during transport can cause stress [88,89]. Moreover, transport has been reported to affect the immune response, increasing susceptibility to different diseases [90,91].

Council Regulation (EC) No 1/2005 [92] regulates animal transport in Europe and contains special requirements for journeys exceeding eight hours, including maximum journey duration, stopping at control posts, and on-road inspections. Transported species have different physiological needs, according to the transport conditions, means of transport used, and climatic zones [93]. Consequently, Council Regulation (EC) No 1/2005 has special requirements for each species, in particular regarding vehicle design and maximum journey duration. In addition, regardless of journey duration, the position of the animals in the vehicle during transport can affect skin blemishes and meat quality [94].

For pigs, transport to the slaughterhouse is a stressor, affecting their health and welfare and, consequently, their carcass quality [95]. During transport, pigs are subjected to many adverse situations including weather conditions [96].

For cattle, loading and unloading are often more stressful than the journey itself [97,98]; however, there are no regulations that define the appropriate conditions or time limits for these procedures. This may be because they are typically short (normally taking less than 15 min) or because there is no simple and non-invasive method for scoring the stress imposed by loading and unloading [99].

The transport of broilers is considered a critical point in the production chain [100], causing possible consequences on their welfare [101]. In fact, broilers are exposed to intense stressful conditions during transport from the farm to the slaughterhouse, and long-term deprivation of water and feed is linked to yield losses at slaughter [102]. In addition, changes in climatic conditions during transport (temperature, relative humidity and air flow) are important stressors for broilers [103] and are not fully controllable in the vehicles used for broiler transportation. Indeed, the microclimate of shipments can be influenced by climatic conditions during transport [104]. Therefore, transport distance and duration, as well as climatic conditions, can interfere with broiler welfare and behaviour [105] and, ultimately, with their performance [106,107].

Nevertheless, animal welfare during transport is difficult to measure and interpret [104]. For this reason, other measurements of animal welfare are needed, such as bruises on the carcass, which are considered important animal-based performance variables. The assessment of bruises can improve transport conditions and reduce economic losses [108].

European Regulations in the Field of Animal Transportation

There have been many different Community rules on animal transport over the years. The first to be issued was Directive 91/628/EEC relating to the protection of animals during transport and amending Directives 90/425/EEC and 91/496/EEC (the latter two Directives concern veterinary and zootechnical controls applicable to the trade in certain live animals and products of animal origin and to live animals originating from third countries being introduced into the Community). Subsequently, changes were made to Directive 91/628/EEC through Directive 95/29/EC and a series of regulations and decisions have been produced that concern particular areas, among which the most notable are:

- Council Regulation (EC) No 1255/97 of 25 June 1997 concerning Community criteria for staging points and amending the route plan referred to in the Annex to Directive 91/628/EEC;
- Council Regulation (EC) No 411/98 of 16 February 1998 on additional animal protection standards applicable to road vehicles used for the carriage of livestock on journeys exceeding eight hours;
- Commission Decision 2001/298/EC of 30 March 2001 amending the Annexes to Council Directives 64/432/EEC, 90/426/EEC, 91/68/EEC and 92/65/EEC and to Commission Decision 94/273/EC as regards the protection of animals during transport;
- Council Regulation (EC) No 1040/2003 of 11 June 2003 amending Regulation (EC) No 1255/97 as regards the use of staging points.

Following these rules, the Council of the European Union invited parties to submit proposals to ensure the effective implementation and strict enforcement of existing legisla-

tion, improve the protection and welfare of animals, as well as to prevent the occurrence and spread of infectious animal diseases and put in place more stringent requirements to prevent pain and suffering in order to safeguard the welfare and health of animals during and after transport.

This invitation gave rise to the latest regulatory act relating to the transport of live vertebrate animals within the Community, namely Council Regulation (EC) No 1/2005 on the protection of animals during transport and related operations; this regulation, with effect from 5 January 2007, modified a series of previous Directives and Regulations and is still in place today.

The main innovations contained in Council Regulation (EC) No 1/2005 are: empowerment of operators such as keeper, transporter, drivers and guardians, for which legal obligations are clearly specified; identification of a transport manager; need for greater training of drivers, guardians and staff who look after the animals, with specific courses, examinations and issuance of a certificate of suitability essential for carrying out the activity; greater controls also based on the use of new technologies (satellite navigation systems); obligation to fill in the travel log for all long journeys (over 8 h in exchanges between member countries and 12 h for trips within national boundaries); more restrictive rules for authorizing transporters (traceability, emergency plans, training courses, etc.); greater regulation of what happens before and after transport (for example, in ports and slaughterhouses), with rules governing loading and unloading operations and the movement of animals; establishment for each Member State of a contact point through which to exchange information and mutual assistance in the field of application of the regulation; definitions of the infringement notification procedures between the competent authorities that issue the authorizations to transporters, the vehicle approval certificates or the certificates of competence of the personnel responsible for looking after animals.

The new regulation, consistent with the fundamental principle that animals must not be transported in conditions such as to expose them to unnecessary injury or suffering [109], applies to transport carried out in connection with trade in live vertebrate animals, whether that is for transport carried out for one's own account or for transport carried out on behalf of third parties. It was necessary in order as far as possible to limit long journeys, which are one of the major causes of stress for transported animals [86,87].

Council Regulation (EC) No 1/2005 involves not only transporters proper, but also breeders, traders, operators of collection centers, control posts and slaughterhouses as the loading and unloading of animals represent other important moments of transport-related stress.

The new provisions, however, do not apply to transport carried out by breeders of their animals with their own means of transport up to a maximum distance of 50 km or carried out for reasons of seasonal transhumance, just as they do not apply to persons carrying out animal transport for a maximum distance of 65 Km; this is, for example, clarified in Italy Ministry of Health memorandum No DGVAX/45209-Pi.6.bh/2 of 14 December 2006 as well as by the Provision of 20 March 2008—in the State-Regions Agreement—concerning “Initial provisions for authorizing the transport of live animals”, published in the Italian Official Journal general series No 118 of 21 May 2008.

Council Regulation (EC) No 1/2005 also instructs Member States to autonomously establish rules on penalties applicable to infringements of the provisions of this Regulation and take all necessary measures to ensure that they are implemented. The penalties provided for must be effective, proportionate and dissuasive. Member States shall communicate these provisions to the Commission, as well as the provisions for the application of Article 26 and subsequent amendments thereto. In case of violations of the provisions of Council Regulation (EC) No 1/2005, the Italian Competent Authority will apply Legislative Decree No 151 of 25 July 2007 containing the sanctioning provisions regarding animal welfare during transport.

3.4. Animal Protection at the Time of Killing

Slaughterhouses have the critical responsibility of ending the lives of animals to produce meat for human consumption while maintaining high standards of animal care [110]. To guarantee appropriate animal handling and management at slaughter plants, proper flooring must be available in animal handling areas, beginning on the trailer, and extending all the way through the restrainers and the lairage facilities [111]. Moreover, adequate training in slaughterhouse practices should be required to make sure that the slaughter procedures are carried out by people with an appropriate level of competence [112].

The protection of animals at the time of killing is regulated by Council Regulation (EC) No 1099/2009 of 24 September 2009 [113]. This regulation establishes that animals shall only be killed after stunning and the loss of consciousness and sensibility shall be maintained until their death. The stunning method plays a very important role throughout the whole production chain, from animal welfare to meat quality and public health [114]. However, the derogation from stunning is confirmed in case of religious slaughter taking place in slaughterhouses, leaving a certain level of discretion to each Member State. Although religious slaughter is considered a humane method, there are some animal welfare concerns related to the pain resulting from neck incision, distress during exsanguination, and the extended duration until loss of consciousness [115–117]. Stunning the animal before slaughter is mandatory in the European Union, USA, Australia, New Zealand, South Africa, Brazil, and East Asian Countries, but it is not permissible in many Muslim countries. Although there are exceptions, several stunning methods have been accepted by Malaysia, Indonesia, and some Muslim communities in the UK, Sweden, Germany, Norway, Switzerland, and Denmark, provided that the animal is stunned but alive until it is slaughtered [118]. There is no broad regulation in the EU on slaughter without stunning; individual countries decide for themselves. A total ban on ritual slaughter is applicable only in Sweden, while in Poland, Denmark, and Greece, it can only be performed after the animal has been previously stunned [118].

Some studies [58] have monitored animal stress during the slaughtering phases, trying to compare traditional procedures, which include stunning and religious procedures where stunning is not contemplated. The plasma cortisol measured for monitoring the stress of the animals showed greater variation between the two methods of slaughtering during the exsanguination phase. Therefore, cortisol plays a central role in the process of protein and fat degradation. Moreover, increased levels of cortisol, even in the late slaughtering phases, may alter the organoleptic characteristics of the meat, such as a considerable decrease in marbling fat, which negatively affects meat flavour and tenderness [119].

3.5. Animal Welfare and Animal Health

Acute stress caused on the farm often turns into chronic stress, because in nature the animal can avoid the source of stress, for example by running away. Conversely, production animals cannot remove stress, as environmental conditions persist [120].

Stressful conditions can cause harmful responses, such as the inability to produce effective responses to infections [121] or can make the animal more vulnerable to disease [122,123] showing that the stress to which ruminants are subjected affects the performance and health of animals and how chronic stress can affect product quality, food processing efficiency and reproductive success.

High neonatal mortality rates in lambs, calves and piglets are often caused by hypothermia, maternal malnutrition, and by gastrointestinal and respiratory injury [124]. These diseases are related to (i) incorrect housing of animals, (ii) inadequate staff training, (iii) incorrect colostrum management and (iv) absence of a positive relationship between resting hours and production [125].

Stress and disease affect growth [126], reproduction [127] and production. Tremetsberger et al. [128] evaluated the association between animal welfare and health through the Welfare Quality® protocol before and one year after the introduction of improvement

actions. The study showed that producers with a Welfare Quality score corresponding to “no disease” had higher technical efficiencies.

Furthermore, Chatterton et al. [129] showed that diseases on farms affected the environmental profile. Indeed, the disease with the greatest influence on the environmental performance of a cow was Johne’s disease, with a 24% increase in the footprint; for Salmonella and BVD, an increase in emissions of 16–20% is estimated; hepatic fasciculation, IBR, lameness and mastitis have an impact of between 7 and 10%. Less important effects are those estimated for calf diarrhoea and pneumonia. Chatterton et al. [129] also report the estimates for beef cows. A healthy farm should correspond to a footprint of 17.1 kg of CO₂ eq./1 kg of meat; however, where diseases are present, the footprint is greater than 6.6%.

Hospito and Sonesson [130] used the LCA methodology to assess the environmental performance of a reference farm compared to that of farming which, thanks to the adoption of appropriate measures, has a lower incidence of mastitis (15% compared to at 18%). The lower incidence of mastitis allows for better environmental performance, such as a reduction in the carbon footprint per kilogram of milk by 2.5% or the consumption of non-renewable resources by 5.8%. Mostert et al. [131] simulated the effect of clinical mastitis on the intensity of greenhouse gas emissions (kg of CO₂ eq./kg of milk); the disease is associated with an increase in the carbon footprint of 6.2%, due to milk waste, reduction in production and prolonged calving interval. Another very frequent and economically relevant bovine disease is ketosis. Mostert et al. [132] studied the effects of its subclinical form on some environmental indicators. It was found that the emission intensity of greenhouse gases increases by 20.9 kg CO₂ eq. in the case of subclinical mastitis, due to the greater distance between birth and conception, the elimination of milk, the reduction in production and the greater number of culled animals.

At the farm level, we know that rational husbandry that allows for healthy, well-developed and fertile animals and that follows protocols of attention to animal welfare is one of the main strategies for reducing the environmental impact of livestock production [133].

4. Antibiotics, Antimicrobial Resistance, and Animal Welfare

Most of the literature on the consequences of the emergence and spread of antimicrobial resistance (AMR) among animals relates to the risks of transfer to people, and thereby a potential impact on public health. However, it must be considered that one of the reasons to use antibiotics is to treat animals suffering from bacterial infections, and AMR in animal pathogens can lead to therapy failure with a direct negative effect on animal health and welfare. This aspect has received little or no scientific attention, and the burden of AMR on animal health is poorly investigated [134]. By contrast, much emphasis has been given to the use of antibiotics in food-producing animals in the form of growth promoters (AGP) and the treatment of healthy animals for metaphylactic or prophylactic purposes (Table 1) [135].

Table 1. Non-therapeutic use of antimicrobials in food-producing animals.

Terminology	Scope	Dosage	Current Legislation (EU)
Antibiotic growth promoters	Increased growth of animals or feed efficiency	Sub-therapeutic	Total ban (since 2006)
Metaphylaxis	Control of a bacterial disease by treating healthy animals during an outbreak	Therapeutic	Restrictions (starting from January 2022)
Prophylaxis	Administration to healthy animals to prevent diseases during high-risk phases of production	Therapeutic	Restrictions (starting from January 2022)

AGPs have been banned in the European Union since 2006 [136] and in the USA since 2017 [137]. Moreover, according to the Regulation of the European Parliament on veterinary medicinal products, as from January 2022, prophylaxis and metaphylaxis in Europe should be kept to a minimum and considered an exception rather than a rule [138].

An overall decrease of 34% in the global use of antimicrobials (AMU) in food-producing animals for the years between 2015 and 2017 is highlighted by the 5th OIE report on AMU in animals. The reduced AMU seems to be strictly related to the ban and the recommendations

to avoid the use of AGPs. In fact, a total of 112 out of 170 countries enrolled in this report declared that they did not use AGPs, regardless of the presence of any regulations [139].

From the Bans to the Good Practices: How to Minimize AMU

The misuse of antibiotics in the past as AGPs contributed to the general perception that antibiotics are incorrectly used and/or they should not be used in food-producing animals at all. For instance, according to an interview by the Eurobarometer Agency in 2018, more than half of European citizens are not aware that AGPs have been banned in Europe since 2006, and a third of them think that sick animals should not be treated with antibiotics [140]. Those beliefs are in striking contrast with the rights of animals as living beings to be treated and their welfare. In addition, the goal of creating ‘antibiotic-free’ farms is achievable only in short-term production systems (such as the poultry meat industry). In a recent survey, farmers and vets declared that the switch to raising animals without antibiotics is due mainly to market pressures, and less commonly for health-related reasons, such as to reduce AMR or to improve animal health and welfare [141].

In general, it is imperative (i) to treat animals appropriately and when necessary, to ensure animal health, (ii) to implement alternatives to the use of antibiotics in major farm animals to curtail rising AMR and its impact on human morbidity and mortality. Some researchers suggest that a shift to less intensive rearing and increased attention to hygiene can resolve many of the situations where the disease and stress load on animals might warrant the use of antibiotics and augment the risk to human health [142,143]. To promote responsible AMU, international and national guidelines have been issued with the dual purpose of ensuring therapeutic efficacy and mitigating resistance [144].

Management strategies and preventive-medicine programs that can be used to reduce disease incidence and thus AMU in food-producing animals are as follows: (i) providing stringent controls on hygiene, population dynamics, feed quality, and environmental conditions to prevent or reduce stress; (ii) eradicating/controlling specific diseases; (iii) optimizing nutrition to enhance natural immunity as a preventive measure to lessen the consequences of abrupt changes in conditions for animals (for example, transport and overcrowding); (iv) breeding for genetically disease-resistant livestock [145].

The processes involved in disease eradication or control are often costly in the short run, but they can be economically justified in specific situations, generally when the public health risk is substantial. Moreover, the judicious use of antibiotics is related to documented diagnosis of the presence of a bacterial pathogen and the choice of the proper drug by means of in vitro susceptibility tests.

Alternative strategies such as vaccines and biosecurity must be exploited. Biosecurity may be defined as all measures taken to prevent both the introduction and the spread of infectious (and parasitic) agents on the farm. It can broadly be divided into “external” biosecurity, focused on preventing introduction of infectious agents, and “internal” biosecurity, focused on preventing their spread within an individual farm, and hopefully their further dissemination via farm waste [146]. Several authors have found an association between lower prevalence of respiratory infections in cattle and high biosecurity levels [147,148]. High standards of biosecurity play a pivotal role in programs for reducing AMU in pig and poultry farms [149]. Other authors have highlighted a statistically significant lower AMU with improved levels of welfare on beef farms in Italy [150]. Altogether, biosecurity and welfare practices are strictly related to each other and have to be improved, as they contribute, just as vaccination protocols do, to lowering the risk of disease and hence the need for AMU [149].

5. Conclusions

Humans are increasingly affecting the climate and the earth’s temperature by burning fossil fuels, cutting down forests and farming livestock. This adds enormous amounts of greenhouse gases (carbon dioxide, methane and nitrous oxide) to those naturally occurring in the atmosphere, thus increasing the greenhouse effect and global warming [151].

Through this study, we attempted to clarify how the implementation of animal welfare standards can lead to a reduction in the use of antibiotics and a reduction in the environmental impact of intensive farms, whereas the current system of intensification of agriculture and livestock rearing would lead to an increase in greenhouse gas emissions of 77% by 2050. These emissions could contribute to an increase in world temperature of close to 2 °C [152].

In this context, a new farm management system must be introduced, one that is more friendly to the environment through greater attention to animal welfare and the correct use of veterinary drugs. Animal production should not be dependent on antibiotic use. However, if animals get sick and treatment is indicated, antibiotics should continue to be given, compliant with responsible use. Such use should be in parallel with good management, good housing, appropriate nutrition for preventing enteric diseases and a high level of external and internal biosecurity on farms, to ensure that the infection pressure is kept at a minimum level. On the other hand, EU Regulation 2016/429 on transmissible animal diseases (Animal Health Law), explains that “animal health and welfare are linked: better animal health promotes better animal welfare, EU 2016/429 and vice versa” [153].

In Italy, the Ministry of Health, with the support of the National Reference Centre for Animal Welfare, has developed a protocol known as “Classyfarm” based (i) on the regulations in force concerning the protection of animals on farms, (ii) on the checklists already used for checks by public veterinary services and (iii) on the most recent studies available on the subject [154].

In this perspective, it seems clear that the effective application of animal welfare standards, as well as a better involvement of all actors in the livestock industry-including institutions-could lead to a new, and more sustainable, farming approach [155].

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