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# Farm Animal Welfare and Human Health

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## KEYWORDS

farm animal welfare, CAFOs, sustainable intensification, human health, aquaculture

## ABSTRACT

*The paper examines the relationship between farm animal welfare, industrial farm animal production, and human health consequences. The data suggest that when the animal welfare of land-based farm animals is compromised, there are resulting significant negative human health consequences due to environmental degradation, the use of non-therapeutic levels of antibiotics for growth promotion, and the consequences of intensification. This paper accepts that even if meat and fish consumption is reduced, meat and fish will be part of the diet of the future. Industrial production modified from the current intensified systems will still be required to feed the world in 2050 and beyond. This paper identifies the concept of sustainable intensification and suggests that if farm animal welfare is improved, many of the human health consequences of intensified industrial production can be eliminated or reduced. In water-based farm animal production, many new systems are resulting in a product that actually protects the environment and can be done at industrial levels without the use of antibiotics.*

## **Introduction**

If we accept that a diet of the future will include fish and meat (even at a reduced level than the current western diet), then the welfare of the animals we eat will continue to be an important moral concern. How animal welfare is defined dictates conditions that are and are not morally acceptable.

Worldwide, industrial farm animal food production is approximately 50% of the total food animal production, while in the developed world, this is closer to 90+ % [1, 2]. Current industrial food animal production is significantly ethically challenged; however, this author believes that animal protein will continue to be a significant part of our future supply of food. It is also recognized that there are movements to eat less meat and fish and thus reduce the amount of animal-based protein in the diet. This paper will look at the moral issues associated with industrial food animal production and approaches to continue producing industrial farm animal protein in ways that are less ethically challenged, i.e., sustainable intensification. The issues that will be examined are animal welfare, environmental degradation, human health consequences, and cost.

Fraser provides a detailed characterization of the concept of animal welfare and the impact of intensification on animal welfare [3]. Since the 1950s animal welfare has been described as the five

freedoms (freedom from hunger and thirst; freedom from discomfort; freedom from pain, injury and disease; freedom to express most normal behaviors; and freedom from fear and distress; Table 1) [4, 5] (Bramble report) and most recently, Marian Dawkins [6] presented a simplified but informative construct. She describes animal welfare as defining what the animal needs and what the animal wants. Several important activities have informed the animal welfare discussion. These include the 2008 Pew Commission report, *Putting Meat on the Table* [7], the EU Welfare Quality principles [8] published in 2009, and Nestlé’s 2014 animal product sourcing policy [9].

**Table 1. The five freedoms<sup>†</sup>**

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<ol style="list-style-type: none"> <li>1. Freedom from hunger or thirst: ready access to fresh water and an adequate and nutritious diet</li> <li>2. Freedom from discomfort: an appropriate environment including shelter and a comfortable resting area</li> <li>3. Freedom from pain, injury or disease: including appropriate and timely treatment when necessary</li> <li>4. Freedom to express (most) normal behavior: sufficient space, proper facilities, and company of the animal’s own kind</li> <li>5. Freedom from fear and distress: ensuring conditions and treatment which avoid mental suffering</li> </ol>
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<sup>†</sup> Data from the report of the Technical Committee to enquire into the Welfare of animals kept under intensive livestock husbandry systems. Presented to the Parliament by the Secretary of State for Scotland and the Minister of Agriculture, Fisheries and Food by Command of Her Majesty, December 1965

**Table 2. Criteria that underpin the Welfare Quality® assessment systems<sup>†</sup>**

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<ol style="list-style-type: none"> <li>1. Animals should not suffer from prolonged hunger, i.e., they should have a sufficient and appropriate diet.</li> <li>2. Animals should not suffer from prolonged thirst, i.e., they should have a sufficient and accessible water supply.</li> <li>3. Animals should have comfortable resting places</li> <li>4. Animals should have thermal comfort, i.e., they should neither be too hot nor too cold.</li> <li>5. Animals should have enough space to be able to move around freely</li> <li>6. Animals should be free of physical injuries.</li> <li>7. Animals should be free of disease, i.e., farmers should maintain high standards of hygiene and care.</li> <li>8. Animals should not suffer pain induced by inappropriate management, handling, slaughter, or surgical procedures (e.g., castration, dehorning)</li> <li>9. Animals should be able to express normal, non-harmful, social behaviors, e.g., grooming.</li> <li>10. Animals should be able to express other normal behaviors, i.e., it should be possible to express species-specific natural behaviors such as foraging.</li> <li>11. Animals should be handled well in all situations, i.e., handlers should promote good human-animal relationships</li> <li>12. Negative emotions such as fear, distress, frustration, or apathy should be avoided whereas positive emotions such as security or contentment should be promoted.</li> </ol>
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<sup>†</sup> Data from Welfare Quality, 2009. <http://www.welfarequality.net>

**Table 3. Highlighted conclusions from “Putting Meat on the Table^ Pew Commission report (2008): impact of industrial farm animal production<sup>†</sup>**

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<p>U.S. policy and laws allow for highly compromised animal welfare.</p> <p>Industrial farm animal production negatively impacts the environment, is of great concern for the social justice of farming communities and farm and related workers, and has significantly human health consequences.</p>
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<sup>†</sup> Data from the Pew Commission Report (2008). <http://www.ncifap.org/>

The Welfare Quality principles (Table 2) [8], the work of a large group of scientists from Europe and South America, expanded on the Brambell report (as codified by the Federation of Animal Welfare Council) of the five freedoms (Table 1). The Pew Commission study, *Putting Meat on the Table* [7], examined the impact of intensification on human health, the environment, social justice, and animal welfare. Its major conclusions are summarized in Table 3. Nestlé, the largest food company worldwide, implemented a policy in 2014 to only source animal products (meat, eggs, and dairy) from animals that have lived their lives according to the five freedoms—as a minimum standard [9]. Most recently, many other companies (Panera, Shake Shack, Chipotle, United Egg Producers (UEP) among others) have also demonstrated concern and established policies toward better farm animal welfare.

In the developed world, almost all farm animals raised for food are produced by intensive operations involving several hundred to thousands of animals confined either in a building or on feed lots (concentrated animal feeding operations) [1]. Current intensified practices do not meet even minimal international guidelines of the five freedoms and thus are of central moral concern. The issue of sustainable intensification is being addressed by some of the newly developing systems of sustainable intensification that do meet the five freedoms and beyond (for a discussion of sustainable intensification, see Godfray et al. [10]).

One consistently raised issue is the cost of food produced with acceptable levels of animal welfare versus industrially produced animal protein. Norwood and Lusk [11] provide an in-depth analysis of the costs of farm animal welfare. Their review in some areas is not critical as they accept some information without the benefit of toxicological evaluation. For example, they state that low levels of hormones, pesticides, and antibiotic residues in meat are of no health concern. This may unfortunately not be accurate, as residues may still induce a biological response; however, this has not been well studied to date. They provide data on the cost of enhanced animal welfare versus traditional industrial production for eggs and pork. Their data confirm what we have learned while working on the Pew Commission, that eggs from caged or cage-free chickens differ by less than a penny an egg, and that pork may be about 50 cents more per pound from sheltered pastured as compared to industrial (about a 15% increase) [11]. These findings demonstrate that the current retail price differentials are due to marketing and consumer acceptance. It is important to note that the retail price of industrial animal protein is greatly decreased by subsidies which do not currently benefit the owner-operated and owner-controlled smaller producers but only industrialized production [7].

More important are the costs of industrially produced animal protein that are known as externalities. These include the human health consequences, environmental degradation, and the impact on social justice. These have been well described in the Pew Commission report, *Putting Meat on the Table* [7]. On all issues of cost, much further independent research is needed to truly evaluate the real costs of industrial, organic, small holder, and other production approaches.

### **Current Farm Animal Production**

In the USA (and most of the developed world), about 95% of all land-based farm animal production comes from very large production sources [1]. Small farms selling animal products through farmers' markets and farm stands contribute less than 5% of the food supply, although this seems to be increasing over the last few years. Even entities that pledge to raise their own food (mainly crops) are unable to do so completely. For example, Green Mountain College in Vermont is able to provide about 12% of the food for its student body (approximately 825 students), with a target goal of 20% by the end of the decade.

It is possible that over time, there will be shifts in dietary habits when less meat is consumed, with increases in consumption of high protein vegetables, insects as food, or other production method (tissue

culture) that will decrease the consumption of animal protein derived from living animals. However, in the absence of significant changes in dietary consumption, large production sources will continue to be necessary to provide sufficient animal protein to meet dietary preferences. This is particularly important as consumption of animal protein in less developed countries increases and, in some cases, approaches consumption of the developed world. While strategies focused on reducing consumption of animal protein may contribute to the relative reduction of total protein intake that is derived from meat, the absolute amount of animal protein will likely remain high in the next decades. This will be due to the size of the population, rapid changes in dietary patterns in developing countries [12, 13], and the fact that dietary changes require time to make an impact, as it is harder to change dietary habits among middle-aged and older adults, compared to earlier in life [14]. A central question is thus whether there are other approaches to industrial-scale (intensified) production that will allow adequate production of food animals (or food animal protein), preserve the environment, protect or even enhance (e.g., through better nutrition) human health and well-being, and meet acceptable standards of animal welfare. That is, can we ethically produce adequate (what is needed for adequate nutrition and/or what is desired) amounts of farm animals to feed the world of over nine billion people along with their companion animals? The focus of this paper is on the industrial systems typical of developed countries.

Current practices of intensification, often called concentrated animal feeding operations (CAFOs), contribute to environmental degradation, negative consequences to public health, and raise issues of animal welfare [7]. These same methods, however, provide large amounts of what seem to be inexpensive animal protein. Animal protein so produced, however, might not be truly less expensive. After taking into account the many externalized costs (health impacts on consumers and neighboring communities, government subsidies), these intensified practices may be as or even more costly than more agrarian or traditional production methods

In general, the comments in this paper refer to industrial large-scale production methods and not small-scale production owner-operated and owner-controlled pasture-based farms. This emphasis should not be interpreted to mean that small-production animal farming raises no moral issues; it does, and some will be identified within the text. However, climate change, non-therapeutic use of antibiotics, and issues of animal welfare—all of which impact human health—are far more pressing considerations in high-intensity production of farm animals than in pasture-based approaches [1, 7].

Regarding the non-therapeutic levels of antibiotics used in farm animal production, the US FDA recently (finalized in 2012) proposed voluntary guidelines recommending that sale of antibiotics for growth promotion (a non-therapeutic use) be stopped [15]. It appears that most producers accepted this recommendation. However, the use of non-therapeutic levels of antibiotics for “disease prevention” is still acceptable [16].

It is noteworthy that the protocol of lifetime dosing using non-therapeutic levels of antibiotics for disease prevention is similar if not identical to the protocol for their use in growth promotion [17].

Thus, using non-therapeutic levels of antibiotics, which are often the same antibiotics used in the control of human disease, for disease prevention in farm animals still has very negative impacts on human health [7]. It is important to note that short-term low dose levels of those antibiotics not used for human use can have specific benefits at times of weaning for pigs and shipping of calves (personal communication, David Fraser, see also reference [18]).

## Animal Welfare and CAFOs

Recognizing the need for some standardization of animal welfare practices, a commission was empowered in the UK in 1959. The commission's report, known as the *Brambell report* [5] after its chair, Sir Roger Brambell, provided criteria for animal welfare that are known as the five freedoms (Table 1). In 2009, the European Union enlarged the five freedoms concept through a series of conferences and workshop and defined a new term, *Welfare Quality* [8]. In both the *Brambell report* and the subsequent report, *Welfare Quality*, the ability of an animal to express its natural behavior (experience its innate "animalness"; what Bernard Rollin, following Aristotle, calls its *telos*) is a major criterion that must be included in any practice aimed at providing animal welfare. The intensification of animal production in the USA (and elsewhere) results in conditions that do not allow animals to express their natural behavioral repertoire. A natural behavior of pigs, for example, is to defecate in a designated area separate from their daily living area. When an animal is in a cage with a cement or even slotted floor, they are forced to live on their excrement, causing, at a minimum, distress, but possibly ill health as well. Vertical integration (when a company owns all aspects of production of a food animal, from birth to death, and sometimes including the preparation of table-ready food) and the resulting intensification as found in CAFOs have greatly and negatively modified the welfare of farm animals. If one uses the five freedoms as a guide, then these animals have access to food and water, but the others are fully absent or only partially satisfied.

Not all small-scale production meets Welfare Quality standards. Animals on pasture experience large variations in weather, are potentially subjected to predators, and may not receive the same oversight as an animal in a concentrated facility. But the esthetics of a pastured animal are exceptionally pleasant and the range of motion considerably enhanced, allowing the animal to express its *telos*, and to have what many understand to be a "good" life for that species. Owner operated/controlled small-scale production is often closer to husbandry, an early acceptance of the obligation to promote and protect animals. Husbandry is taking great pains to put one's animals into the best possible environment to meet their physical and psychological needs, and then augmenting their ability to survive and thrive by providing them with food, protection from predation, water, medical attention, help in birthing, and so on [19, 20].

In most countries, animal welfare is provided and defined by laws and regulations. In the USA, the Animal Welfare Act (AWA) does not define animal welfare. Moreover, the AWA *excludes* farm animals from consideration. US Federal regulations only regulate how farm animals are transported and slaughtered. And most recently, there are discussions to increase the possible rate of slaughter, which will impact not only animal welfare but also worker safety. The current rate of slaughter already occurs at dangerous speeds that result in worker injury. Abusing farm animals (cruelty) is not currently against the law, and recently proposed legislation would criminalize the mere exposing of abuse of farm animals [21]. An investigative report by Michael Moss in the Jan. 20th 2015 New York Times, on the Department of Agriculture's Animal Research Facility in Nebraska provides evidence that a lack of oversight resulted in animal abuse and cruelty, none of which is illegal but is immoral [22].

Although there are no official animal welfare standards in the USA, industrial food animal producers have their own conception of animal welfare. They equate welfare with productivity as measured by the number of eggs laid or weight gain of the animal [23]. Despite numerous debates on the proper understanding of animal welfare [3, 24], it is clear that this reduction of welfare to productivity is incomplete and unacceptable. A few examples of the impact of CAFOs on the welfare of animals can illustrate this point.

### *Chicken Production*

In commercial production, the large companies are vertically integrated. A vertically integrated company owns all aspects of production of a food animal, from birth to death, and sometimes including the preparation of table-ready food. This can include a hatchery, contracts with many farmers to grow chickens under specified conditions, and a plant to process one million or more chickens per week. Each chicken goes from a chick to table-ready in 6 weeks (42 days), and the industry refers to each chicken as a “unit,” further distancing itself from the concept of the chicken as a living creature [7]. To provide some indication of the magnitude of production, I quote Nicholas Kristof of the *New York Times*, March 12, 2014 [25]: “Tyson, one of the nation’s biggest companies, slaughters 135,000 head of cattle a week, along with 391,000 hogs and an astonishing 41 million chickens. Nearly all Americans regularly eat Tyson meat at home, at McDonalds, at a cafeteria, at a nursing home.” Tyson is one of the largest producers in the world and among the four major chicken producers in the USA. Some of the negative effects of this intense production methodology, as previously identified, includes impacts on animal welfare, the environment, farmers, farm and processing workers, the local community, and human health.

As explained in the next section, antibiotic use at nontherapeutic levels results in the development and spread of antibiotic-resistant bacteria that have significant human health consequences. As a result of genetics and antibiotics, chickens grow so quickly that their bones cannot support their weight, they peck at each other (“give me some room”), and their waste is so concentrated (many chickens, little space per chicken) that the ammonia in the waste is irritating to the eyes and mucous membranes of the animals as well as to humans who happen to be in this environment [7]. As a result of bacterial contamination, a relatively recently introduced practice in chicken preparation includes carefully washing all utensils and surfaces that come in contact with the raw chicken; otherwise, serious contamination and illness can result [26, 27]. In a recent incident reported in the US press, even chicken that had been cooked to 165°F resulted in illnesses [28].

Large industrial processors have vertically integrated production. The farmer (often referred to as the grower) is a part of the chain. The grower owns the mortgage on the farm and the animal waste. All else—the chicken, the profits, feed manufacture (feed formulas), and post-slaughter processing—are owned and controlled by the integrator. This same arrangement exists for other land-based industrial production of animal protein [7]. At the present time in the USA, a handful of companies control more than 95% of all animal protein sold. The growers are what is generally called “the family farm,” and in the USA, they constitute tens of thousands of households, if not more. These are owner-operated, but not owner-controlled; they are controlled by the integrator.

### *Swine Production*

Conditions of confinement for pigs are small group pens or individual stalls [7]. When pigs are at full weight, these pens are very crowded. Both crowded pens and individual stalls prevent the animals from having anything like a species-specific typical life. For example, pigs in individual stalls cannot interact with each other, nor can they turn or sometimes even lie down. All of the issues associated with intensification, including the inability to perform normal behavior and lack of access to the outdoors, are the same in cages or pens. In the case of swine, the quantity of animal waste is huge—about 13 times greater per animal, in fact, than per human. Human waste is always treated in the developed world, whereas swine waste is not treated and is either used as fertilizer or makes its way into runoff and waterways [7]. The resulting contamination has important negative environmental consequences such as contamination of rivers and coastal waterways. Animal waste in pastured animals does not cause the same problems and supports soil health.

## *Cattle Production*

Cattle start their lives on pasture but are moved into feed lots (intensified conditions) where the diet is changed to corn and grain after about 6 months. This diet changes their digestive systems, allows them to grow faster, and changes the quality and quantity of fat to a less healthful variety for humans. Fat from grass-fed animals has higher levels of conjugate linoleic acid [29] and approaches the fat composition of fish. By concentrating these animals in feedlots, they are also forced to live on top of their excrement.

All of these examples converge in demonstrating that CAFOs cannot even approximate the five freedoms and fall very far short of Welfare Quality standards. Stating it another way, CAFOs do not allow animals to have what they need or what they want [6]. Land-based industrial animal production, including egg and dairy production, affects all of the issues of moral concern identified in the Global Food Ethics Project [30].

However, there are research and commercial developments aimed at sustainably intensified approaches that do provide a higher level of animal welfare. These include, for example, the Rondel system [31] for egg-laying hens and recirculating aquaculture facilities (see later). The Rondel system meets the five freedoms, a lower environmental impact, the need to fit in with the landscape, greater transparency for the public, and an economically sustainable enterprise for the farmer.(28).

In January, 2015, the National Research Council/National Academy of Science (NRC/NAS) released a report: *Critical Role of Animal Science Research in Food Security and Sustainability* [32]. This report, known as the Goldstein report named after its Chairman, Bernard Goldstein, identifies research priorities and recommends government and private sector support for these activities. The report confirms the finding of the Pew Commission Report (*Putting Meat on the Table*) that farm animal-based research needs to be focused on producing adequate animal-based food products ethically. The report essentially confirms the necessity for greater adherence to the five freedoms, with “modified production systems that provide more opportunities to express natural behaviors” [32]. This Pew Commission report, “Putting Meat on the Table,” is not cited in this newer NAS report, although many of its major conclusions are consistent. The reasons for not referencing the Pew Commission report are unclear.

## **The Consequences of Intensification on Human Health and the Environment**

In all animal species, the non-therapeutic use of antibiotics or antimicrobials is used to prevent diseases that are themselves the result of current intensification procedures [19]. Although many of these diseases are of ancient origin, the intensity and prevalence coincides with the development of CAFOs. There is little question that the use of these drugs, as well as breeding practices and genetics, have changed the rate of growth and feed conversion in these animals. As a consequence, the price of animal products at the retail level has been greatly decreased. However, is this a real decrease in cost or have the costs merely been shifted? How have these practices resulted in troubling human health consequences? What impact have they had on rural communities? Numerous studies have demonstrated that the cost of food is not reflected in the retail price [33–35]. Human health issues, environmental degradation, and community impact (social justice) are all part of the cost that each and every person pays. Whether the cost of industrial food is actually higher or lower than that produced by small farms at retail price, as indicated earlier, awaits a true analysis.

The human health consequences of the use of nontherapeutic levels of antibiotics are, however, well researched and significant [36]. There is no question that the use of antibiotics for growth promotion or “disease prevention” has resulted in the spread of antibiotic-resistant infections, such as methicillin-

resistant *Staphylococcus aureus* (MRSA), in humans. In the USA, 80% of all antibiotics produced are sold for use in farm animals, primarily for non-therapeutic purposes (Table 4).

Importantly, the therapeutic use of antibiotics to cure diseases in an animal is ethically required. When used in this way, the antibiotic is given at a therapeutic dose only for the period of time needed to effectively treat the disease. By contrast, the non-therapeutic use of low-dose antibiotics for growth promotion or disease prevention requires the drug to be given over majority of the life of the animal. This low dose exposure in animals has a significant and negative effect on human wellbeing [37].

CAFOs generally find their way into rural and impoverished areas. The impact on the community can be devastating [7, 38]. In addition to MRSA, there is always a decrease in property values, impairment of quality of life issues, and poor esthetic. During the Pew Commission hearings, a young girl that lived next to a CAFO testified about the air quality. She stated that when she woke the first morning in her college dorm, she thought she was dead because “there was no smell.” While this is a single case report, air pollution studies near CAFOs has supported worsened air quality and adverse respiratory outcomes observed in persons living near CAFOs [39].

With intensification comes a change in diet for all species. These animals now consume industrially produced crops. Some pesticides that are known to affect human health (e.g., atrazine) are also used on crops to feed animals [37]. An underexplored area is the effect of these pesticide-treated crops on animal health and human health as a contaminant of the animal products. Atrazine, the second most widely used pesticide in the USA, is banned in Europe but allowed in the USA [40].

It seems that the cost of cheap meat (eggs and dairy included) comes at a very high price.

**Table 4. Antibiotics by the numbers (USA)<sup>†</sup>**

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80% of all antibiotics sold in the USA are used in farm animals
29.9 million pounds for livestock
7.7 million pounds to treat sick people
\$21–34 billion cost to US health system of antibiotic-resistant infections (2013)
Antibiotic resistance in humans:
2 million illnesses
23,000 deaths
7% of 400 different antibiotics given to animals have been reviewed by the FDA.

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<sup>†</sup> Data from National Geographic, March 2015

### *Aquatic Species*

At the present time, some 50–60% of fin and shellfish used for human food are farm-raised. The vast majority of wild caught aquatic animals are generally harvested using large nets, as opposed to being individually line caught. Net harvesting has resulted in depletion of many species, especially cod, and cut productivity of breeding grounds. Overharvesting has been one of the factors resulting in the need for aquatic farms [41].

There are several different approaches currently in use or development for aquatic farming facilities including small production facilities, open-waterway nets, and technologically advanced water recirculation systems.

Paul Greenberg, in *Four Fishes*, identifies the issues in wild harvested and farmed sea animal products [41]. Although one might think that wild is the best to eat, this may not be correct. Depending on the qualities of the flesh desired, farmed may be a tastier and environmentally better choice. Further, when fish are farmed in some of the recirculating systems, there is considerable sparing of resources, and a very high-quality product results.

Atlantic salmon, a species of fish not necessarily from the Atlantic Ocean, is one of the most abundantly farmed fish and is raised in all types of facilities. Antibiotics are used in some, but not all, systems [41]. In addition, it is possible to use alternative protein-sourced (e.g., grain-based) feeds (although salmon are mainly carnivores) instead of fishmeal-based feeds [42]. Although the fish farming industry has often been criticized for the excessive consumption of wild fish to produce farmed fish, this is becoming less of an issue as feed formulations have improved substantially. In certain life stages, in water recirculation systems, the feed ratio to production can be as low as 0.7 (0.7 units of fish food to produce 1.0 units of fish for human consumption). In some recirculation systems, the waste is used as plant fertilizers or for energy production, resulting in efficient utilization of food resources and great sparing of water [43].

Several marine species are being farmed in the University of Maryland, Baltimore County research facility in Baltimore, Maryland and have been taken to new and incredibly high quality of production. This facility raises multiple species of fish including bass, sea bream, and amberjack. The system is completely recirculating, with the waste filtered and used for the production of energy and the volatile wastes used to grow algae for conversion to biofuels. It is a very green way to intensively grow marine species for consumption.

One interesting species is the oyster. When done well, oyster farming may actually recapture areas for raising better oysters and at the same time, purify the water for other fish populations [44].

The animal welfare issues in farmed fishing are more difficult to gauge. Many of the species school and that is what they are forced to do in the tanks. In properly managed water recirculation facilities, the fish are healthy, show little evidence of body damage, and have low feed conversion ratio. Their density, however, is greater than in the wild. Works by Martins et al. [45] and Huntingford et al. [46] did an excellent job of identifying items that should be considered in any evaluation of fish welfare. Welfare Quality has not defined conditions for aquatic species. However, the considerations that are used for land-based animals can be adapted for aquatic species. A recent study has evaluated enrichment (wall colors and shapes) for the marine species sea bream [47]. Fish animal welfare is in need of a thorough study similar to Welfare Quality.

Many issues of fish welfare are under active investigation. At the present time, the slaughter I personally witnessed at the Fresh Water Institute was rapid, without any struggling on the part of the fish and appeared to be humane. The fish were placed on a wet platform and gently fed into a chute. Upon entering the chute an electrical stunning followed by gill displacement terminated the animal's life. There was no indication of stress on the fish and the speed of the killing was very quick (possibly less than a second). This type of slaughter is currently used commercially but it is not the only method of killing in the industry.

Moreover, some farming enterprises for aquatic species have negative effects on the fish, the environment, and the human health. For example, some shrimp farms are environmentally unsustainable, and many of the aquatic operations are significantly affected by disease.

### *Other Animal-Based Protein Sources of Food*

Important research is currently investigating the potential for insects to serve as a source of protein for humans and animals [48]. Depending on one's view about the value of insect life and the potential of insects to suffer, the production of insects for food will raise fewer concerns about animal welfare than the production of birds, mammals, and aquatic life. Also, in 2013, animal muscle was successfully grown in tissue culture as a proof of concept that cultured "meat" has the potential to be a source of food. This first demonstration involved the production of a "hamburger" from tissue-cultured cow muscle. More research is needed, however, to evaluate the costs (including water and energy) and organoleptic characteristics of cultured meat. If the nutritional content and taste of cultured meat can be well controlled and if the production process successfully scaled up at affordable prices, cultured meat could be an important source of animal protein that will not raise any animal welfare issues. It clearly will be used as animal feed if and when the price becomes competitive.

### **Conclusions**

No one system of food animal production (or for that matter crops) will work for all situations. The local food movement in the developed world, which could be considered as only currently affordable for wealthy sections of the population, entails consumers getting locally produced food from the farm or the farmers' market, if not growing or raising it themselves. This is a remarkable and increasingly popular trend, with farm stores selling not only produce and meat but also dairy products, cured meats as well as breads, pastas, and other locally made food products. Most recently, many local food vendors are now accepting SNAP benefits and money from food assistance programs.

In most cases, the animal foods produced in owner-operated, owner-controlled small-scale farms and sold in the local food movement context of wealthy countries meets, at an acceptable level, the issues of moral concern identified in the Global Ethics Project identified above. In the world of land-based food animals, the small owner-operated, owner-controlled farm has few animals, and the treatment the animals usually receive can be called husbandry. In some areas of the USA, farmers are banding together to raise animals on pasture and then sell them through one or more local stores. In this case, the meat is hormone- and antibiotic-free, respects the environment, and sells at a somewhat higher (but should not be more than about 20% higher) price than meat produced industrially. However, this approach will not produce the quantities of meat produced in intensified facilities.

In the developed world, food animal production at the industrial level requires considerable change to meet any plausible account of ethical acceptability. Intensification and single-species production have significant consequences on the environment, animal welfare, and human health and use resources at unsustainable levels.

The issue of animal welfare is central if we are to feed the world ethically. The lack of adequate animal welfare practices for industrially raised animals is unacceptable. The Pew Commission report cited above described the animal welfare as "inhumane," but did not use the word *cruel* as some of us would have liked. In addition to strategies aiming at reducing animal protein consumption and increasing vegetable protein consumption, intensified practices will likely be needed to provide sufficient animal protein to meet the nutritional needs of over nine billion people. These practices, however, will have to be modified significantly from our current practices if they are to be sustainable and resilient, incorporate good animal welfare, and protect human health and the environment.

Animal welfare approaching the EU Welfare Quality standards [8], with the five freedoms as a minimum, must become incorporated into the developing framework for feeding the world of nine billion-plus people ethically.

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### **Compliance with Ethical Standards**

Alan M. Goldberg declares that he has no conflict of interest.

This article does not contain any studies with human or animal subjects performed by any of the authors.

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### **References**

1. National Geographic. 'The future of food' special compilation issue. 2015;227(3):1–113.
2. Ash C, Jasny BR, Malakoff DA, Sugden AM. Food security. Feeding the future. Introduction. *Science*. 2010 Feb 12;327(5967): 797–833.
3. Fraser D. *Understanding animal welfare: the science in its cultural context*. Oxford: Wiley-Blackwell; 2008.
4. Five Freedoms. 2015. Available from: [https://en.wikipedia.org/wiki/Five\\_freedoms](https://en.wikipedia.org/wiki/Five_freedoms).
5. Brambell Committee. Report of the technical committee to enquire into the welfare of animals kept under intensive livestock husbandry systems. 1965. Report No.: 2836.
6. Dawkins MS. *Why animals matter: animal consciousness, animal welfare, and human well-being*. USA: Oxford University Press; 2012.
7. The Pew Commission on Industrial Farm Animal Production. *Putting meat on the table: Industrial farm animal production in America*. 2008. <http://www.ncifap.org/>.
8. Welfare Quality Network. <http://www.welfarequalitynetwork.net/network>. Accessed 18 Feb 2016.
9. Nestlé announces farm animal welfare commitment. 21 August 2014. Available from: <http://www.nestle.com/media/newsandfeatures/nestleanimal-welfare-commitment>. Accessed 1 Dec 2014.
10. Godfray HC, Beddington JR, Crute IR, Haddad L, Lawrence D, Muir JF, et al. Food security: the challenge of feeding 9 billion people. *Science*. 2010 Feb 12;327(5967):812–8.
11. Norwood FB, Lusk JL. *Compassion, by the pound: the economics of farm animal welfare*. Oxford: Oxford University Press; 2011.
12. Delgado CL. Rising consumption of meat and milk in developing countries has created a new food revolution. *J Nutr*. 2003 Nov;133(11 Suppl 2):3907S–10S.
13. Popkin BM, Adair LS, Ng SW. Global nutrition transition and the pandemic of obesity in developing countries. *Nutr Rev*. 2012;70(1): 3–21.

14. Chernoff R. Nutrition and health promotion in older adults. *J Gerontol A Biol Sci Med Sci*. 2001;56(suppl 2):47–53.
15. FDA Announces Voluntary Withdrawal of 16 Antimicrobials for Use in Food-Producing Animals. 2014. <http://www.fda.gov/AnimalVeterinary/NewsEvents/CVMUpdates/ucm392461.htm> Accessed 30 March 2015.
16. Nachman KE, Smith TJ, Martin RP. Antibiotics: call for real change. *Science*. 2014;138(6167):136.
17. Animal and plant health inspection service (APHIS). Questions and answers: judicious use of antimicrobials in food-producing animals. 2014. [https://www.aphis.usda.gov/publications/animal\\_health/content/printable\\_version/faq\\_antimicrobial\\_drugs.pdf](https://www.aphis.usda.gov/publications/animal_health/content/printable_version/faq_antimicrobial_drugs.pdf). Accessed 01 Feb 2016.
18. Beef procedures: antibiotic use. <http://www.sdstate.edu/vs/extension/beef-procedures-antibiotics.cfm>. Accessed 01 Feb 2016.
19. Rollin B. Putting the horse before Descartes: my life's work on behalf of animals. Philadelphia, PA: Temple University Press; 2011.
20. Goldberg A, Rollin B. Husbandry and industry: animal agriculture, animal welfare, and human health. Roni A. Neff, editor. In: *Introduction to the US Food System: Public Health, Environment, Equity*. 1st ed. San Francisco: Wiley-Jossey Bass.; 2014. p. 294–9.
21. Iowa governor signs law penalizing animal rights activists. 2012. <http://www.reuters.com/article/usa-iowa-agriculture-idUSL2E8E605920120306>. Accessed 01 February 2016.
22. Moss, M. U.S. research lab lets livestock suffer in quest for profit. 2015. <http://www.nytimes.com/2015/01/20/dining/animal-welfare-at-risk-in-experiments-for-meat-industry.html>. Accessed 16 February 2016.
23. Animal husbandry guidelines for U.S. Egg laying flocks. 2016. <http://www.unitedegg.org/information/pdf/UEP-Animal-WelfareGuidelines2016.pdf>. Accessed 15 Feb 2016.
24. Fraser D. Animal welfare and intensive animal production: a new model for change. 2014. Prepared for Feeding the World, Ethically Meeting October 6–9, 2014 Ranco, Italy. Available from: <http://www.bioethicsinstitute.org/globalfoodethics/the-7-by-5-agenda-for-ethics-and-global-food-security>
25. Kristof N. The unhealthy meat market. 2014. [http://www.nytimes.com/2014/03/13/opinion/kristof-the-unhealthy-meat-market.html?\\_r=0](http://www.nytimes.com/2014/03/13/opinion/kristof-the-unhealthy-meat-market.html?_r=0).
26. The high cost of cheap chicken. 2014. <http://www.consumerreports.org/cro/magazine/2014/02/the-high-cost-of-cheap-chicken/index.htm>. Accessed 30 Mar 2015.
27. United States Department of Agriculture (USDA). Chicken from farm to table. 2015. [http://www.fsis.usda.gov/wps/portal/food-safety-education/get-answers/food-safety-fact-sheets/poultrypreparation/chicken-from-farm-to-table/ct\\_index](http://www.fsis.usda.gov/wps/portal/food-safety-education/get-answers/food-safety-fact-sheets/poultrypreparation/chicken-from-farm-to-table/ct_index). Accessed 30 Mar 2014.
28. Pierson D. Costco unsure how cooked chicken was tainted in salmonella outbreak. 2013. <http://articles.latimes.com/2013/oct/14/business/la-fi-mo-costco-recall-20131014>. Accessed 01 Mar 2014.
29. Smit LA, Baylin A, Campos H. Conjugated linoleic acid in adipose tissue and risk of myocardial infarction. *Am J Clin Nutr*. 2010 Jul;92(1):34–40.
30. Global food ethics project. <http://www.bioethicsinstitute.org/globalfoodethics/the-7-by-5-agenda-for-ethics-and-globalfood-security>.
31. Rondeel <http://www.rondeel.org/>. Accessed 30 March 2015.
32. National Research Council. Critical role of animal science research in food security and sustainability. Washington DC: The National Academies Press; 2015.
33. Tegtmeier EM, Duffy MD. External costs of agricultural production in the United States. *Int J Agric Sustain*. 2004;2(1):1–20.

34. Delate K, Duffy M, Chase C, Holste A, Friedrich H, Wantate N. An economic comparison of organic and conventional grain crops in a long-term agroecological research (LTAR) site in Iowa. *Am J Altern Agric*. 2003;18(02):59–69.
35. Imhoff D. Overhauling the Farm Bill: the real beneficiaries of subsidies. *The Atlantic*. 2012 <http://www.theatlantic.com/health/archive/2012/03/overhauling-the-farm-bill-the-real-beneficiaries-of-subsidies/254422/>(March 21).
36. Carrel M, Schweizer ML, Sarrazin MV, Smith TC, Perencevich EN. Residential proximity to large numbers of swine in feeding operations is associated with increased risk of methicillin-resistant *Staphylococcus aureus* colonization at time of hospital admission in rural Iowa veterans. *Infect Control Hosp Epidemiol*. 2014;35(02):190–2.
37. Silbergeld EK, Graham J, Price LB. Industrial food animal production, antimicrobial resistance, and human health. *Annu Rev Public Health*. 2008;29:151–69.
38. Schinasi L, Horton RA, Guidry VT, Wing S, Marshall SW, Morland KB. Air pollution, lung function, and physical symptoms in communities near concentrated swine feeding operations. *Epidemiology*. 2011 Mar;22(2):208–15.
39. Casey JA, Kim BF, Larsen J, Price LB, Nachman KE. Industrial food animal production and community health. *Curr Environ Health Rep*. 2015;2(3):259–71.
40. Hayes, T. What is atrazine? And why do we love it? <http://www.atrazinelovers.com/m1.html>. Accessed 15 Jan 2016.
41. P. G. *Four fish: the future of the last wild food*. New York: Penguin Press; 2010.
42. Tibbetts, JH. In booming aquaculture industry, a move to plant-based food for fish. 2015. [https://e360.yale.edu/digest/in\\_booming\\_aquaculture\\_industry\\_a\\_move\\_to\\_plant-based\\_food\\_for\\_fish/4523](https://e360.yale.edu/digest/in_booming_aquaculture_industry_a_move_to_plant-based_food_for_fish/4523). Accessed 15 Jan 2016.
43. McCollow, K. Aquaponics revives an ancient farming technique to feed the world. 2014. <http://www.newsweek.com/2014/05/23/aquaponics-revives-ancient-farming-technique-feed-world-251020.html>. Accessed 20 Nov 2015.
44. National Centers for Coastal Ocean Science (NCCOS). Measuring parasites and disease in U.S. oysters and mussels. 2015. <http://coastalscience.noaa.gov/news/coastal-pollution/measuringparasites-disease-u-s-oysters-mussels/>. Accessed 30 Mar 2015.
45. Martins CI, Galhardo L, Noble C, Damsgård B, Spedicato MT, Zupa W, et al. Behavioural indicators of welfare in farmed fish. *Fish Physiol Biochem*. 2012;38(1):17–41. Huntingford FA, Adams C, Braithwaite V, Kadri S, Pottinger T, Sandøe P, et al. Current issues in fish welfare. *J Fish Biol*. 2006;68(2):332–72.
46. Batzina A, Dalla C, Tsopekos A, Papadopoulou-Daifoti Z, Karakatsouli N. Environmental enrichment induces changes in brain monoamine levels in gilthead seabream *Sparus aurata*. *Physiol Behav*. 2014;130:85–90.
47. Fanzo J. Ethical issues for human nutrition in the context of global food security and sustainable development. *Glob Food Sec*. 2015;12(7):15–23.