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The Welfare of Transgenic Farm Animals

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1. Introduction

As part of a burst of deregulatory activity in the dwindling days of the Bush administration, the U.S. Food and Drug Administration proposed guidelines for the approval of genetically engineered farm animals for the American food supply. Imagine "double muscled" beef cattle born so enormous they can be extracted only via Caesarian section, a dairy cow capable of generating ten times more milk than a calf could suckle (if she were allowed, that is), a hen laying so many eggs she risks a prolapse (laying her own uterus), turkeys so top-heavy they are physically incapable of mating, and chickens with such explosive growth they have to be starved lest they risk aortic rupture (Renema, 2004). Imagine a world in which farm animals have been so genetically modified for rapid muscling that billions suffer in chronic pain from skeletal disorders that impair their ability to even walk.

Unfortunately, this is the world we already live in. All of these abominations exist today, products of conventional techniques of genetic manipulation, such as artificial selection and insemination, hormone-induced superovulation, and embryo splitting and transfer. Genetic engineering, the creation of transgenic farm animals whose genes have been modified through biotechnology, goes a step further, giving agribusiness an additional tool to stress animals towards their biological limits at the expense of their health and welfare—and, potentially, ours as well.

2. Production-related disease related to extant breeding technologies

2.1 Mighty mice

Ever since the early Eighties when it was demonstrated that one could nearly double the size of mice by engineering them to produce rat or human growth hormones, the livestock industries have been clamoring to make use of this technology (Palmiter et al., 1982, 1983; Westhusin, 1997). Double-muscling is a genetic defect maintained in certain breeds of beef cattle caused by a mutation of a gene which regulates muscle growth. Not only do births of such calves require surgical intervention, their tongue muscles may be too enlarged to suckle, leading to death (Lips et al., 2001; Uystepruyst et al., 2002). Unable to move sufficiently in the womb due to their unnatural size they may be born with their joints locked in place and be unable to stand (Lips et al., 2001). The inherent welfare problems have led some European countries to consider banning the intentional breeding of such cattle on animal welfare grounds (Anonymous, 2010a). Reads one editorial in the *British*

Veterinary Journal: "I wonder how many [farmers] could truly claim to be proud of breeding animals which they know are unfit to survive without recourse to elective surgery" (Webster, 2002).

The creation of the "mighty mouse," however, with up to *triple* the muscle mass has reignited hopes within the agribusiness community that this mutation could successfully be transferred to sheep, pigs, chickens, turkeys, and fish (McPherron et al., 1997; McPherron & Lee, 1997; Rodgers & Garikipati, 2008).

2.2 Milk machines

Today's dairy cows endure annual cycles of artificial insemination, mechanized milking for 10 out of 12 months (including 7 months of their 9-month pregnancies), and giving birth. Over the past century, selective breeding has tripled the annual milk yield per cow to about 20,000 pounds. It took the first half of the century to force the first ton increase, but since the 1980s, the industry has managed to milk an extra ton of production per cow every eight or nine years. According to Bristol University Emeritus Professor John Webster in the Department of Clinical Veterinary Science, "The amount of work done by the [dairy] cow in peak lactation is immense. To achieve a comparable high work rate a human would have to jog for about 6 hours a day, every day." This excessive metabolic drain overburdens the cows, who are considered "productive" for only two years and are slaughtered for hamburger around their fourth birthday when their profitability drops, a small fraction of their natural lifespan (Dewey, 2001).

Turning dairy cows into milk machines has led to epidemics of so-called "production-related diseases," such as lameness and mastitis, the two leading causes of dairy cow mortality in the United States. We all remember the sick and crippled dairy cows being dragged and beaten at that California dairy cow slaughter plant in 2008. That loss of body condition is in part a direct result of this extreme selection for unnaturally high milk yields.

That slaughter plant investigation triggered the largest meat recall in history for fear the cows might be infected with mad cow disease. A cow's natural diet—grass—can no longer sustain such abnormally high levels of milk production. They must be fed feed concentrates such as grains or slaughter waste. Today's dairy cows may be forced to eat a pound a day of meat, blood, and bone meal, euphemisms, as described by a leading feedstuffs textbook, for "trimmings that originate on the killing floor, inedible parts and organs, cleaned entrails, fetuses...."

Ever increasing rates of mastitis, (United States Department of Agriculture [USDA], 2008a) udder infections, have led to the extensive use of antibiotics in the dairy industry, including classes of drugs important to human medicine such as penicillin, erythromycin, and tetracycline (USDA, 2008b). A 2005 survey of Pennsylvania dairy herds even uncovered that about 1 in 5 operations were injecting cows with a third generation cephalosporin, a class of antibiotics critical for the treatment of serious infections in children (Call et al., 2008). The concern is that by selective breeding for an overstressed caricature of an animal, the dairy industry's reliance on pharmacological crutches may in turn breed antibiotic resistance to drugs necessary for human medicine (Alcaine et al., 2005).

The mastitis epidemic in the national dairy herd also affects milk quality. American milk has the highest allowable pus cell concentration in the world, legally allowing over 300 million "somatic" cells per glass, 90% of which are neutrophils (pus cells) when there is an udder infection of that severity (United States Public Health Service, 2003; Ruegg, 2001). The industry, however, has always argued that it doesn't matter how inflamed and infected the udders of our factory farmed dairy cows are, because of pasteurization—it's essentially cooked pus, so there's no food safety risk. But just as parents may not want to feed their children fecal matter in meat even if it's irradiated fecal matter, they might not want to feed their children pasteurized pus.

And you can taste the difference. A 2008 study published in the *Journal of Dairy Science* found that cheese made from high somatic cell count milk had both texture and flavor defects as well as increased clotting time compared to milk conforming to the much more stringent European standards. Treating animals as mere commodities is not only bad for the animals and risky for people, but may result in an inferior product.

2.3 Sweating like a pig

The intensive breeding of pigs for increased muscle mass has led to a susceptibility to porcine stress syndrome, in which electric prodding and other stressors can trigger muscle rigidity, high fever, and acute death from what's called malignant hyperthermia, also known as "hot death" (Casau, 2003; Wendt et al., 2000; Anonymous, 2010b). It costs the industry hundreds of millions of dollars a year, but the reason the genetic defect hasn't been eliminated is that the mutation that puts pigs at risk for this disease is the same mutation that adds 2-3% muscle mass to the dressed carcass weight (MacLennan & Phillips, 1992).

Postmortem, their muscles can become pale, soft, and sweaty, which many consumers find objectionable. As the director of the Muscle Biology Laboratory at the University of Wisconsin told the *New York Times*, "You don't want to sell your deli meat with a spoon" (Casau, 2003).

2.4 Shell game

Whereas ancestors to the modern-day chicken laid about 25 eggs a year, today's laying hens produce more than ten times that number. After about a year they are considered "spent." By the end their bones are so brittle because of the excessive draw of calcium from their skeletons for egg shell formation that up to a third of hens have freshly broken bones at slaughter.

The loss of muscle tone from excessive egg-laying, along with consumer demand for "jumbo" eggs, places hens at risk for the prolapse of part of their reproductive tracts during egg-laying (Keshavarz, 1990; Zuidhof, 2002). This can lead to bleeding, infection, and death from cloacal cannibalism, as stressed and overcrowded cage-mates peck at the exposed organ (Newberry, 2004; Zuidhof, 2002). The steroidal sex hormone activity associated with heavy egg production is thought to be why both benign and cancerous tumors are so common in commercial birds and also why hens are predisposed to salpingitis. This pelvic infection can lead to the buildup of masses of caseous exudate (oozing material with a cheese-like consistency), which can expand and end up fatally filling the body cavity.

2.5 Butterballs

Ben Franklin's tree-perching "Bird of Courage" has been transformed into a flightless mammoth bred to grow so fast, a group of veterinary researchers concluded, "that they are on the verge of structural collapse" (Wise & Jennings, 1972). Wild turkeys grow to be 8 pounds (Healy, 1992). The average turkey grown today is more than 28 pounds (National Agricultural Statistics Service, 2007). Their skeletons cannot adequately support such weight, leading to degenerative hip disease, spontaneous fractures, and up to 20% mortality due to lameness in problem flocks (Julian, 1984). An editor at *Feedstuffs*, the leading U.S. agribusiness weekly, wrote that "turkeys have been bred to grow faster and heavier but their skeletons haven't kept pace, which causes 'cowboy legs.' Commonly, the turkeys have problems standing…and fall and are trampled on or seek refuge under feeders, leading to bruises and downgradings as well as culled or killed birds" (Smith, 1991).

Commercial strains may not only outgrow their skeletons, but their cardiovascular systems as well. Modern day turkeys have been bred to grow so fast that up to 6% of modern-day turkey flocks simply drop dead from acute heart failure at just a few months of age (Mutalib & Hanson, 1990). It still may make good economic sense in the end. The sudden deaths of turkeys has in fact been regarded by some in the industry as a sign of "good flock health and fast growth rate as in the case of sudden death syndrome (flip-over) in broiler chickens" (Mutalib & Hanson, 1990). As one producer wrote, "Aside from the stupendous rate of growth…the sign of a good meat flock is the number of birds dying from heart attacks" (Baskin, 1978).

2.6 Why they can't cross the road

The commercial breeds of chickens raised for meat, so-called "broilers," probably suffer the most. Compared to 1920, broilers now grow twice as large in half the time, reaching slaughter weight in around 6 weeks. To put their growth rate into perspective, the University of Arkansas Division of Agriculture calculates, "If you grew as fast as a chicken, you'd weigh 349 pounds at age 2" (Boersma, 2001).

Their hearts and lungs can't keep up. Due to this breeding for rapid growth, a hundred million chickens in the United States every year succumb to sudden death or "flip-over" syndrome, since the birds are often found on their backs after dying in a fit of convulsions and wing-beating (Julian, 2004). These are baby birds, only a few weeks old, dying of heart attacks. One poultry specialist mused in the trade publication *World Poultry*, "Mathematically, it is evident that the present rate of improvement in growth cannot be continued for more than a couple of decades, or the industry will be faced with a bird that virtually explodes upon hatching" (Urrutia, 1997).

Today's broiler chickens are crippled with inbred physical disabilities, from "twisted-leg" deformities to avulsed and ruptured tendons. At six weeks, broiler chickens have such difficulty supporting their grossly overweight bodies that they are forced to spend most of their time lying in their own waste, leading to an increased incidence of painful contact burns such as "breast blisters" from the ammonia released from the decomposing excrement (Estevez, 2002; Weeks et al., 2000). Those unable to hobble using their wing tips as crutches or crawl on their shanks to food and water won't make it to slaughter.

A review published in 2003 in an industry text *Poultry Genetics, Breeding and Biotechnology* concluded, “There is no doubt that the rapid growth rate of birds used for meat production is the fundamental cause of skeletal disorders, nor that this situation has been brought about by the commercial selection programmes used over a period of 40-50 generations” (Whitehead et al., 2003). There is no doubt that the industry is to blame. More than a quarter of broilers have been found to have difficulty walking in chronic pain. With 9 billion chickens produced annually in the United States, that means billions of animals are made to suffer every year because of this genetic selection for extreme productivity, a pedigree of pain.

According to Professor Emeritus Webster, “Broilers are the only livestock that are in chronic pain for the last 20% of their lives. They don’t move around, not because they are overstocked, but because it hurts their joints so much” (Erlichman, 1991). This chronic pain experienced by our freakishly heavy modern day chickens and turkeys “must constitute,” Webster concludes, “in both magnitude and severity, the single most severe, systematic example of man’s inhumanity to another sentient animal” (Webster, 1995).

Two prominent poultry researchers, however, offer the following economic analysis:

“Two decades ago the goal of every grower was to ensure that the flock grew as rapidly as possible. However, the industry has developed a broiler that, if grown as rapidly as possible, will achieve a body mass that cannot be supported by the bird’s heart, respiratory system or skeleton.

“The situation has forced growers to make a choice. Is it more profitable to grow the biggest bird possible and have increased mortality due to heart attacks, ascites, and leg problems, or should birds be grown slower so that birds are smaller, but have fewer heart, lung and skeletal problems?...A large portion of growers’ pay is based on the pound of saleable meat produced, so simple calculations suggest that it is better to get the weight and ignore the mortality” (Tabler & Mendenhall, 2003).

2.7 Look what's coming to dinner

Chickens and turkeys aren't the only lame birds. In its final days, the Bush Administration's promise to “sprint to the finish” involved rolling back restrictions on smokestack emissions, commercial ocean fishing, and mountaintop removal coal mining (Smith, 2008). Overshadowed by election coverage, in September 2008 the FDA released draft guidelines to move the approval of genetically engineered farm animals in the U.S. food supply one step closer to reality (Food and Drug Administration, 2009).

The Biotechnology Industry Organization claims that the genetic engineering of farm animals offers “tremendous benefit to the animal by enhancing health, wellbeing, and animal welfare” (Gottlieb, 2002). Theoretically this technology could be used by industry giants to ameliorate some of the inbred animal “illfare” they have created, but if past performance is any predictor of future behaviour, genetic engineering will just be used to further industry goals of production efficiency at nearly any cost. The meat, egg, and dairy industries recognize that enhanced productivity generally comes at the expense of animal health and well-being. The reason given for not using existing breeding programs to relieve suffering is presumably the same reason biotech resources won't be diverted to improve welfare: doing so, in the words of livestock geneticists in the *Journal of Animal Science*, may "result in less than maximal progress in economic traits" (Kanis et al., 2005).

The primary goal set out for transgenic food animals has explicitly been to improve productivity, so-called "quantitative genetic engineering" concerned with increasing "economic fitness" (Dickerson & Willham, 1983; Pinkert & Murray, 1999). Consider the most widespread current use of biotechnology in animal agriculture, recombinant bovine somatotropin. The injection of this genetically engineered growth hormone increases milk yield in dairy cattle, but also increases the rates of mastitis, lameness, and poor body condition. Yet millions of U.S. dairy cows are repeatedly injected with this genetically engineered hormone throughout their short lives, demonstrating dairy industry priorities—profits at the expense of animal health. More is not always better.

Agribusiness claims in its public relations materials that biotechnology will be used to improve animal welfare, but to date gene constructs designed to express growth factors constitute the largest class of transgenes so far experimentally transferred into livestock (Murray, 1999). It is instructive that the first report of the successful creation of transgenic livestock was the "Beltsville pigs," engineered at a USDA lab in Beltsville, Maryland to express human growth hormone (Hammer et al., 1985). Yes, their feed efficiency modestly improved, but many became lame, lethargic, and uncoordinated with thickened skin and bulging eyes. These pigs also suffered with ulcerated stomachs, inflamed hearts and kidneys and severe joint degeneration. Several of them died during or immediately after confinement in a restraint device, suggesting an increased susceptibility to stress (National Research Council, 2002). Seventeen of the nineteen transgenic pigs created didn't last a year.

Though animal scientists have cited the Beltsville pigs research "as an excellent example of the value of this technology," the results of the now infamous experiment have been used by critics for over 20 years to condemn the genetic engineering of farmed animals on animal welfare grounds (Wheeler et al., 2003). Reliance on laboratory freaks as the centerpiece of one's argument, though, ignores the fact that the technology has improved since those early experiments and, more importantly, overlooks the much larger concern. Given the inefficiency and unpredictability of this still emerging science, attention has been drawn to the unintended consequences, but considering the power of the technology and the sheer number of animals raised for food every year—50 billion land animals alone—what of the secondary effects of the *intended* consequences (Mak, 2008)? Due to agribusiness prioritizing economic fitness over physical fitness, billions of farm animals are already in pain. Now they want to stitch in growth hormones to strain animals even further past their breaking point? DNA technologies have been considered by corporate breeders as the fast lane on what they call the "road to the biological maximum" (Buddiger & Albers, 2007).

Grahame Bulfield, the head of the Roslin Institute, the creator of the cloned sheep Dolly, is quoted as saying:

"The view I take on animal welfare is that the technology itself is a red herring. If an animal is lame because of genetic modification or selective breeding or poor nutrition, or because I kick it, it is wrong that it's lame. So you have to pay attention to the phenotype—that is, to the animal itself—rather than the technique that produces the problem" (Klotzko, 1998).

The speed, power, and ecologically disruptive potential, however, of genetic engineering is unique. Selective breeding is a powerful tool; it is, after all, what enabled humankind to turn a wolf into a poodle, but that was over a period of 14,000 years (Pennisi, 2002). Dramatic changes can be induced by gene manipulation in a single generation, and few of the usual checks and balances imposed by natural selection may apply. In natural or artificial selection, the trait that is chosen comes coupled to a constellation of linked attributes that may help the animal maintain homeostatic balance, as teetering as it may be. Due to the single-gene nature of transgenic change, however, engineered animals may suffer a greater loss of fitness than their selectively bred counterparts in conforming form to function. This has been clearly demonstrated in transgenic fish.

3. Ecological concerns raised by farm animal transgenesis

3.1 Bigger fish to fry

Several species of genetically engineered fish stand ready to be marketed worldwide, transgenic tilapia in Cuba, transgenic salmon in the United States and Canada, and transgenic carp in the People's Republic of China (Kaiser, 2005). The North American AquAdvantage™ salmon is positioned to become the first transgenic animal available for human consumption. Like all farmed animals, farmed fish undergo genetic manipulation through selective breeding to enhance economically favored traits such as rapid growth rate. Genetic selection for salmon size over a period of ten years has been shown to increase average weights by about 60% (Hershberger et al., 1990). Salmon engineered with transgenic growth hormones can be 1100% heavier on average, though, with one fish weighing out at 37 times normal (Devlin et al., 1994).

Yes, some of these transgenic salmon suffer from severe and sometimes fatal cranial disfigurements, but the larger concern surrounds their overall average fitness. The critical swimming speed of salmon genetically engineered to grow twice as fast is twice as slow as the speed of same-sized normal salmon, impairing their ability to forage and avoid predators. Similarly, normal catfish exhibit better predator-avoidance skills compared to transgenic catfish. The concern is that should these transgenic fish escape into the wild—a common occurrence in aquaculture—they could lead to species population extinction (Muir & Howard, 1999).

Male medaka fish genetically engineered with a salmon growth hormone, for example, possess an overwhelming mating advantage compared to wild-type medaka males due to their large body size. While they preferentially attract mates, in the end bigger is not necessarily better. Should their offspring bear a viability disadvantage, mathematical modeling suggests a "Trojan gene effect," where a combination of mating advantage with survivability disadvantage could ultimately lead to the rapid collapse and extinction of both the transgenic and wild fish population in as few as approximately 50 generations should a transgenic male escape into the wild (Howard et al., 2004).

A report from the National Academy of Sciences on animal biotechnology concluded that these potential environment impacts present the greatest science-based safety concern (National Research Council, 2002). The one class of species—fish—considered to pose the highest risk is the one closest to commercialization. The risk is so great that biologic, rather than physical, containment of these animals may be necessary, such as induced sterility. The incorporation of so-called "suicide genes" is under consideration to prevent the genetic pollution of environment (as well as to protect corporate intellectual property rights and investment) (Wheeler et al., 2003). On the other hand, some Purdue University scientists have expressed hope that the Trojan gene effect could itself be harnessed as a tool for biological control: transgenic males could be created and released intentionally to drive wild populations of unwanted species to extinction (Muir & Howard, 1999).

3.2 Narrowing the genetic base

There is also a concern that biotechnology will lead to the loss of genetic biodiversity within farm animal species. An international analysis of commercial poultry breeds published in the *Proceedings of the National Academy of Sciences* found that about half of the genetic diversity of chickens has already been lost. According to the Food and Agriculture Organization of the United Nations, over the last century 1,000 farm animal breeds—about one-sixth of the world's cattle and poultry varieties—have disappeared, with breeds continuing to go extinct at a rate of one or two every week. Transgenesis will be subject to the same pressures that have already led to such a narrowing of the genetic base. Should an engineered line of animals gain a clear competitive advantage, competitors may replace varieties viewed as obsolete. Genetic uniformity increases the vulnerability of monocultures of animals to diseases that could spill over into human populations.

4. Anthropocentric concerns raised by farm animal transgenesis

4.1 Bred to be contagious

The biotech industry touts human benefits as well. Under consideration are cows that produce milk with fewer disease-causing components – fewer allergens, less lactose, or less saturated butterfat, though the industry fears the latter could deleteriously impair the whipping of cream (Gibson, 1991; Jost et al., 1999; Karatzas & Turner, 1997; Reh et al., 2004). Adding human breast milk genes to dairy cow udders has been suggested to improve baby formula (Wall et al., 1997). Incorporation of a humanized version of a roundworm gene into pigs could potentially make pork a source of omega-3 fatty acids and take pressure off diminishing global fish stocks. Pigs have even been implanted with spinach genes (Lai et al., 2006; Young, 2002). Dr. Seuss's signature dish may soon be realized.

Human health concerns, as expressed for example in a February 2009 review in *Critical Reviews in Food Science and Nutrition*, have largely been limited to the potential for growth hormones from genetically enhanced animals to promote human colon, breast, and prostate cancer (Dona & Arvanitoyannis, 2009). The physiological trade-off between productivity and immune function may pose a broader risk, however.

Genetic manipulation for accelerated muscle, milk, and egg production carries an inverse relationship with immune function, a trade-off that has been empirically demonstrated in chickens, pigs, and both beef and dairy cattle. This has been explained by the "resource-allocation hypothesis," which suggests that protein and energy diversion from host defense to breast muscle mass production, for example, explains why chickens with accelerated growth are at risk for increased immune dysfunction, disease morbidity, and disease mortality. As breast mass enlarges, the lymphoid tissue, the immune system organs themselves, shrink.

Before domestication, natural selection chose strong immune systems for survival. After domestication, though, artificial selection concentrated on improvement of production traits with less attention to resistance to disease, resulting in survival of the fattest rather than the fittest. The reason this may pose a human health hazard is that three quarters of emerging human infections diseases have come from animals. Whether it's mad cow, bird flu, porcine Nipah virus, *Strep suis*, or poultry and aquaculture-related foodborne disease, how we breed and raise animals can have global public health implications.

As a crutch to compensate for the imposed immunodeficiency (as well as the often overcrowded, stressful, unhygienic conditions on factory farms) agribusiness pours millions of pounds of antibiotics straight into chicken, pig, cattle, and fish feed to promote further growth and stave off disease, a practice banned in the European Union and condemned by the American Academy of Pediatrics, the American Medical Association, the World Health Organization, and hundreds of other medical and public health organization. Antibiotic resistant bacteria, including the "superbug" MRSA found recently in 70% of pigs tested in Iowa and Illinois, may then transfer to people via contaminated air, water, soil, or food. We may be sacrificing a future where antibiotics will continue to work for treating sick people by squandering them today on animals that are not yet sick at all.

4.2 Chicken surprise

A 1997 scientific expedition to Alaska further underscored the threat of weakened farm animal immunity. Digging up victims of the 1918 flu pandemic discovered frozen in the permafrost for tissue samples, scientists allied with the U.S. Armed Forces Institute of Pathology were able to decipher the genetic code of the killer virus, solving perhaps the greatest medical detective story of all time. The 1918 pandemic was the worst plague in human history, killing more people in 25 weeks than AIDS has killed in 25 years, an estimated 50 million people dead. In 2005, with the entire genome of the 1918 virus finally decoded, the mystery was solved. Humanity's greatest mass murderer turned out to be a bird flu virus. This finding, combined with the unprecedented recent emergence of highly pathogenic bird flu viruses around the world such as H5N1, means that disease losses from selecting or engineering fast growing breeds of chickens with essentially built-in immune dysfunction can no longer just be factored in to the corporate bottom line. Millions of human lives may be at stake.

There has been interest in trying to genetically engineer our way out of these problems. Instead of stopping the cannibalistic feeding of slaughterhouse waste, blood, and manure to cows, for example, researchers are trying to create mad cow disease resistant cattle (Cyranoski, 2003). Instead of removing the strain on overproducing dairy cattle, researchers are working on creating cows that secrete an antibiotic substance directly into their milk to prevent udder infections (Wall et al., 2005). Production-related diseases have become preferred technofix targets presumably because they represent barriers to even greater productivity. The industry may be able to squeeze extra tons of milk from cows secreting antibiotics without rampant mastitis, but the metabolic, musculoskeletal, and painful hoof problems associated with overproduction would be further aggravated. Issues surrounding the Enviropig™ offer a parallel.

4.3 Trojan pig

Trumpeted by the pork industry as the "biggest breakthrough in pig farming since the invention of the trough," a new line of transgenic pigs incorporating a composite of mouse and bacterial genes has been patented to produce manure with less phosphorus: the Enviropig™ (Vestel, 2001). This may allow for the further expansion of swine CAFOs, confined animal feeding operations. Already some CAFOs store hog waste in massive open-air manure pits the size of several football fields, which can burst, spilling millions of gallons of excrement into local watersheds. In one year, 1991, an estimated one billion fish were killed from farm animal manure run-off in North Carolina alone (Zakin, 1999). Enviropigs may produce less phosphorus, but what about the other pollutants in manure—the nitrates which end up in the groundwater leading to miscarriages, birth defects, and "blue-baby syndrome," the hydrogen sulfide emissions that have killed CAFO workers, the ammonia contributing to acid rain, potent greenhouse gases such as methane and nitrous oxide, and the increased asthma rates in adjoining school districts and elevated infant mortality? The pigs aren't the problem; CAFOs are the problem.

In the United States, farm animals produce an estimated 2 billion tons of manure each year, the weight of 20,000 Nimitz-class aircraft carriers. Manure has been found to be the source of more than 100 pathogens and parasites that can infect people, as well as antibiotics, hormones, pesticides, and toxic heavy metals. Enviropigs won't rid CAFOs of the odor, disease, pollution and occupational hazards inherent to intensive confinement. They will, however, be trumpeted as exemplars by the biotechnology industry of the golden age that transgenic farm animals are to herald, as golden rice was used to tout genetically modified crops.

Golden Rice was hyped as the salvation for millions of children threatened with blindness, but cynics argued that Golden Rice was more about the salvation of the beleaguered biotech industry (Anonymous, 2008). The cynics may have been right. In the eight years since its development not a single grain has been sown for consumption, whereas during that same period hundreds of millions of tons of Roundup Ready® crops have been planted worldwide, increasing the global ecological burden of herbicides and herbicide resistance. Similarly, the industry may publicly peddle concepts like the Enviropig™ as a ploy to dampen criticism while slipping past the more lucrative and damaging applications of transgenic livestock.

5. Using biotechnology to improve the welfare of farm animals

5.1 Cui bono?

Animal agriculture has undergone a mass consolidation in recent decades. For example, a handful of corporations now supply most of the breeding stock for all the world's poultry. Soon, the industry predicts, there may essentially be only three poultry breeders in the world. Today, a single pedigree cockerel can potentially give rise to two million broiler chickens. This means that selected or engineered traits can be propagated around the world at an unprecedented rate. The industry can now replace practically the entire global chicken flock in a space of three or four years, affecting the welfare of 50 billion animals for better or for worse.

The genetic engineering of farmed animals is not *necessarily* harmful. Like nearly all tools and technologies, the consequences depend on how it's used. Theoretically, there are numerous applications of biotechnology that could indeed improve the lives of farm animals by undoing the harm of selective breeding, but one has to consider who owns and stands to profit from the technology? Based on the livestock industry's track record one can be certain that in nearly any conflict that arises between production efficiency and animal suffering, profitability will win the day, but there are rare circumstances in which producers and animals may both benefit.

Today's laying hens produce more than ten times the number of eggs than their ancestors, leading to uterine prolapses and critically weakened, broken bones as their skeletal calcium is disproportionately mobilized for shell formation. Egg-laying breeds have been so genetically manipulated—through conventional selection—that it's not profitable to raise male offspring for meat. So hundreds of millions of male chicks every year in the United States are gassed, ground up alive, or just thrown in dumpsters to suffocate or dehydrate to death after hatching. Economically it doesn't make sense to even waste feed on male chicks because they haven't been bred for excessive muscle mass. Engineering hens that lay only female chicks would double the yield for the breeding industry while sparing hundreds of millions of animals a tragic death. Similarly, constructing dairy cows to preferentially deliver females could save a half million male calves from their doomed fate in the veal industry.

Tens of millions of piglets are castrated without anesthesia or postoperative painkillers every year in the United States to prevent "boar taint" of carcasses, a quality considered amenable to genetic manipulation. No federal regulations protect animals on the farm and "standard agricultural practices" such as castration and dehorning are typically exempt from state anti-cruelty statutes.

Dehorning of beef cattle is another painful surgical procedure performed without anesthesia primarily to protect carcass quality, but could be obviated by knocking out the single gene responsible for horn production (Rollin, 1995). Polled (congenitally hornless) breeds already exist, a fact that may make cattle genetically engineered without horns more palatable to the public. Of course if beef cattle weren't crammed so tightly into feedlots there wouldn't be the level of bruising from horns that leads to so much carcass wastage. This raises the question: is it preferable to engineer animals to fit industrial systems, or rather to engineer systems that fit the animals in the first place?

5.2 Carving square pegs into round holes

More than 95 percent of egg-laying hens in the United States are crammed five to seven together into file-cabinet sized wire "battery cages," affording each hen less than a sheet of paper of space on which to live for over a year before she is killed. Nobel Laureate and noted father of modern ethology Konrad Lorenz wrote: "The worst torture to which a battery hen is exposed is the inability to retire somewhere for the laying act. For the person who knows something about animals it is truly heart-rending to watch how a chicken tries again and again to crawl beneath her fellow cagemates to search there in vain for cover." What if this nesting urge could be removed through genetic tinkering, though? This brings to mind the ill-famed blind chicken experiments.

In 1985 poultry scientists published a series of experiments showing that under conditions of intensive confinement congenitally blind hens are more efficient at laying eggs than hens that can see. Under the stressful, barren, overcrowded battery cage conditions, hens can peck each other to death, so the ends of their sensitive beaks are burned off as chicks to minimize the damage they can do. They still peck at one another, though, which can increase feed requirements because body heat is lost from exposed skin due to feather loss. But blind hens don't seem to peck at each other as much, not do they seem to move as much either, another big cost saver in terms of feed efficiency. Feed "wasted" on movement means less energy directed to egg production. The researchers concluded that "genetically blind birds were more efficient in converting feed into products. It is therefore worthwhile to explore further the potential of this mutation in egg-laying strains under cage systems" (Ali & Cheng, 1985).

The general public reacts negatively to the notion of the industry deliberately breeding hens to be blind in order to save on feed costs, but the larger issue remains unaddressed (Lassen, 2006). What has the system come to when animals have to be literally mutilated—whether via debeaking, dehorning, detoeing, desnooding, disbudding, mulesing, comb removal, teat removal, teeth cutting, or tail docking—to fit the industrial model? Rather than creating blind chickens better adapted to confinement, an informed public would likely reject stuffing birds in tiny cages in the first place, as California voters did in 2008, passing a ballot initiative that phases out battery cages by a landslide 27 point spread victory, making it the most popular citizens' initiative in California history. A 2007 American Farm Bureau poll found that a majority of Americans are in agreement that farm animals shouldn't be raised in cages and crates.

5.3 Mike the headless chicken

If demand for the cheapest possible meat continues to grow unabated, some animal welfare scientists have suggested going beyond the design of sightless birds, and moving to brainless. Mike the headless rooster (1945-1947) became a circus sideshow phenomenon after an incomplete decapitation left him with his brainstem intact. He was able to walk, balance on a perch, and, fed with an eyedropper, lived 18 months with no head. In this vein one could theoretically engineer headless chickens, stick tubes down their neck, and have all the meat with none of the misery. Though aesthetically abhorrent, which is worse: raising brainless chickens or a system in which animals might be better off braindead than fully alive?

CIP, Congenital Insensitivity to Pain, is a rare neurological disorder in which children are born unable to feel pain. Due to their susceptibility to injury, they don't live very long, but the industry doesn't need farm animals to live very long. The moral outrage such a breeding program would engender might be tempered should the public become aware of the current paradigm, in which billions of animals are raised to suffer in chronic pain.

These scenarios speak to how far we've strayed from tradition concepts of animal husbandry, how far out of step animal agribusiness is now from mainstream American values—and the industry knows it. Professor Emeritus of Animal Science Peter Cheeke wrote in his collegiate textbook Contemporary Issues in Animal Agriculture:

"One of the best things modern animal agriculture has going for it is that most people…haven't a clue how animals are raised and 'processed.' In my opinion if most urban meateaters were to visit an industrial broiler house to see how the birds were raised…some, perhaps many, of them would swear off eating chicken and perhaps all meat. For modern animal agriculture, the less the consumer knows about what's happening before the meat hits the plate the better" (Cheeke, 2004)

5.4 Meat without feet

The answer may lie in producing meat "ex vivo," outside of a living animal. In 1932, Winston Churchill predicted: "Fifty years hence we shall escape the absurdity of growing a whole chicken in order to eat the breast or wing by growing these parts separately under a suitable medium." He was a few years off, but in 2000 NASA scientists showed that one could start to grow fish flesh in a petri dish.

The first In Vitro Meat Consortium Symposium took place in 2008 at the Norwegian Food Research Institute, bringing together an international cadre of research scientists working on the issue. With the right mixture of nutrients and growth factors, muscle cells may be able to be coaxed to multiply enough times to produce processed meat products such as sausage, hamburger, or chicken nuggets. Meat scientists at Utrecht University in conjunction with a Sara Lee sausage manufacturer subsidiary are currently working off a grant from the Dutch government to produce cultured meat as part of a national initiative to reduce the environmental impact of food production. Theoretically, the entire world's meat supply could be produced from a single cell taken painlessly from a single animal.

Reasoned one animal scientist at the Portuguese Institute for Molecular and Cell Biology:

"Frankly, if the end product is to be the white meat of a month-old broiler chicken or the minced meat of a hamburger, prepared without care and eaten absent-mindedly, why make the detour through a sentient vertebrate which needs kilos of grain just to keep upright and has a brain that may feel fear and frustration?"

Imagine victimless meat, minus manure and methane, fished out oceans, and jungles deforested for fodder. Meat could be grown hygienically, eliminating million of cases of foodborne illness, and more efficiently, since the vast majority of corn, soy, and grain we feed animals now is lost to metabolism—just keeping the animals alive—and making inedible structures like the skeleton. Unnatural, yes, but so is most of what we eat, from bread to yogurt to hydroponic vegetables. There is arguably very little natural about the way our meat is produced today. Biotechnology has the potential to dramatically affect the welfare of farm animals on a massive scale, but whether this effect is positive or negative depends on how it's used and how it's regulated.

6. Meeting consumer expectations

In a dismissal of the charge that biotechnology leads to the treatment of animals as mere commodities, bioethicists at the Danish Centre For Bioethics and Risk Assessment respond: "There is already a tendency to treat animals as mere things in industrial farming" (SandØe & Holtug, 1993). This doesn't justify further erosion of consideration for farm animals, but rather constitutes a call for critical reflection on contemporary practices. As the complete genomic sequences of all farm animals become available, there will be an increasing need for guidelines and guidance as to what is and is not ethically permissible.

Colorado State University Distinguished Professor Bernard Rollin, professor of animal sciences, biomedical sciences, and philosophy, has introduced as a guiding principle the concept of "conservation of welfare": when genetically engineering animals, the transgenic animals should be no worse off afterwards than their parents were (Pew, 2005). Given the volume of current suffering imposed by conventional techniques, though, rather than arguing for the status quo, perhaps a "remediation principle" would be more appropriate. Society could mandate that transgenesis for increased production require the resulting farm animals be better off than their parents. Equipped with such powerful new tools, animal agriculture could use biotechnology to bring itself more in line with rising societal expectations for farm animal care.

In order for biotech companies to recoup their R&D investments and for agribusiness corporations to sell products of this technology, a broad public acceptance is necessary. The most extensive international study of public perceptions was a survey of more than 34,000 residents of 34 countries in Africa, Asia, the Americas, Europe and Oceania in 2000. Only 35% of global consumers were in favor of using biotechnology to increase farm animal productivity (Environics International, 2000). In the United States the percentage of those who found it acceptable to use biotechnology to create faster-growing fish dropped from 32% in 1992, to 28% in 1994, to 23% in 2000 (Hoban, 2004). According to a nationwide survey conducted in 2003 by the Pew Initiative on Food and Biotechnology, the majority of Americans (58%) even oppose scientific research into the genetic engineering of animals (PEW, 2005).

At the same time there has been a groundswell in public awareness and scrutiny over the treatment of animals raised for food. According to a 2007 American Farm Bureau poll executed by Oklahoma State University, 95% of consumers agreed with the statement that "[i]t is important to me that animals on farms are well cared for" and furthermore, 76% disagreed that "[l]ow meat prices are more important than the well-being of farm animals" (Lusk et al., 2007). An Ohio State University survey found that 81% felt farmed animal well-being is as important as the well-being of companion animals, such as dogs and cats (Rauch & Sharp, 2005). The Farm Bureau found that the majority of surveyed Americans oppose the way hundreds of millions of farm animals are raised every year in the United States—the intensive confinement of animals in cages and crates. Three quarters of Americans would vote for a law that would require farmers to treat their animals more humanely, a sentiment reflected in a 2008 Gallup poll recognizing widespread support for the passage of "strict laws" concerning the treatment of farm animals. "It was a little surprising the extent to which the issue of humane treatment of animals is ingrained and widespread in our society," the director of public relations for the Farm Bureau told *Meat & Poultry* magazine. "There's a lot of interest in this" (Newport, 2008).

This emerging social ethic for the welfare of farm animals could be an opportunity for the biotech industry rather than an impediment. A consumer backlash against biotechnology resulting from an application perceived to worsen the plight of billions of farm animals could undermine confidence not only in the food system but adversely affect the public's view regarding medical applications of biotechnology as well as the science of genomics as a whole (Pew, 2005). According to an extensive national survey and focus group discussions published in 1993 by the North Carolina Cooperative Extension Service, the least acceptable applications of biotechnology reportedly appeared to include genetically engineering food animals for accelerated growth (Hoban & Kendall, 1993). By instead redressing the pain and suffering caused by conventional breeding, the biotech industry could improve its public image and reduce the stigma hindering the technology, and agribusiness could address societal concerns while potentially expanding its market share. Either way, the debate over transgenic farm animals may bring to light the excesses of the current breeding paradigm and force the meat egg, and dairy industries to revisit practices they have so far taken for granted.

7. Conclusion

The Pew Commission on Industrial Farm Animal Production was formed to conduct a comprehensive, fact-based, and balanced examination of key aspects of the farm animal industry. This prestigious independent panel was chaired by former Kansas Governor John Carlin and included former U.S. Secretary of Agriculture Dan Glickman, former Assistant Surgeon General Michael Blackwell, and James Merchant, then Dean of the University of Iowa College of Public Health. They released their report in 2008. It concluded: "The present system of producing food animals in the United States is not sustainable and presents an unacceptable level of risk to public health and damage to the environment, as well as unnecessary harm to the animals we raise for food." Animals have already in effect been manufactured to be damaged and diseased (Ott, 1996).

In their report, the National Academy of Science and National Research Council's Committee on Defining Science-Based Concerns Associated with Products of Animal Biotechnology expressed concern that certain farmed animals have already been pushed to the edge: "Indeed," they concluded, "it is possible that we already have pushed some farm animals to the limits of productivity that are possible by using selective breeding, and that further increases only will exacerbate the welfare problems that have arisen during selection" (National Research Council, 2002). Biotechnology could be used to reverse some of the damage, but given animal agriculture's track record of willful neglect, the incorporation of genetic engineering will likely just reinforce current practices and worsen an already broken system.

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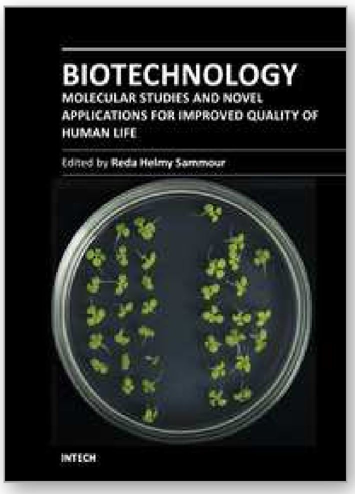

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This book deals with the importance of application of molecular biology as an approach of biotechnology for improvement of the quality of human life. One of the interesting topics in this field, is the identification of the organisms that produce bioactive secondary metabolites. It also discusses how to structure a plan for use and preservation of those species that represent a potential source for new drug development, especially those obtained from bacteria. The book also introduces some novel applications of biotechnology, such as therapeutic applications of electroporation, improving quality and microbial safety of fresh-cut vegetables, producing synthetic PEG hydro gels to be used as an extra cellular matrix mimics for tissue engineering applications, and other interesting applications.

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