Impact Mitigation Strategies for Higher-Welfare Broiler Production

Working Paper

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New Green Normal Consulting

This report was compiled on behalf of Compassion in World Farming by Sandra Noonan [1] with contributions from Dr. Hillary Dalton .[2] In addition to Dr. Dalton, comments were received from Julia Johnson[3] and other third-party experts within the broiler industry.

The report is downloadable from www.thenewgreennormal.com.

To contact the author, email sandra@thenewgreennormal.com.

[1] New Green Normal Consulting

[2,3] Compassion in World Farming

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Highlights

- This report considers the actions necessary to optimize U.S. broiler production for *higher welfare* and *lower environmental impact*, where *higher welfare* is defined as Better Chicken Commitment (BCC)-compliant poultry and *environmental impact* is assessed through the metric of greenhouse gas emissions (GHGe).

- Achieving higher welfare and lower environmental impacts in tandem calls for a *systems-level approach* that considers the broiler production system as an integrated set of upstream, on-farm, and downstream activities. When managing towards BCC compliance and decarbonization, it is useful to consider broiler production through the lens of Scope 1, Scope 2, and Scope 3 emissions where increases in one scope can be offset by decreases in another.

- We use the term *theoretical emissions gap* to discuss the incremental GHGe from BCC-compliant broiler production in the absence of offsetting measures. Available data suggest that the GHGe from higher welfare production are 9-16% higher, before considering interventions to narrow this gap.

- We consider the emissions gap to be theoretical for two reasons: First, there are few peer-reviewed, publicly available life cycle assessments that reflect U.S. production parameters, which differ in important respects from those of other broiler-producing countries. Second, in at least one real-world case, BCC-compliant production has not led to emissions increases.

- The GHGe of a conventional U.S. broiler producer can be decreased by as much as 38% through a combination of changes that reduce upstream environmental impacts from feed ingredients, decrease on-farm emissions, and improve feed efficiency, more than offsetting the theoretical emissions gap.

- More than any other factor, feed production and use influence the theoretical emissions gap between conventional and BCC-compliant broiler production. Two mechanisms for reducing feed-related emissions are (i) achieving the lowest possible feed conversion ratio (FCR) for a given target broiler weight and (ii) decreasing the base carbon footprint of feed ingredients.

- The lower mortality of higher welfare breeds reduces waste and theoretically translates to reduced GHGe, but lower breast meat yields and longer grow-out times to slaughter offset this advantage. A robust body of demand-shifting and demand-mitigation strategies is available to maximize the benefits of higher welfare breeds and align poultry production with corporate decarbonization commitments.

1. Introduction

More than 230 companies have signed on to the Better Chicken Commitment (BCC), a set of practices that promote a higher standard of welfare for broiler chickens. At the same time, many firms have committed to reducing the carbon footprint of their supply chains, known as Scope 3 greenhouse gas emissions. Some industry stakeholders have declared these two aspirations — higher welfare chicken and supply chain decarbonization — as incompatible, given that certain components of the BCC call for larger quantities of feed and housing.

The premise of this report is that the Better Chicken Commitment is an *impetus and opportunity* to reduce the environmental impacts of broiler production beyond the levels that conventional producers have achieved. While this task is difficult, it is not impossible. "Welfare-friendly changes in chicken systems can be achieved without a compromise in their environmental impacts," notes one researcher.[1] As for conventional U.S. broiler production, industry representatives rightly assert that current practices achieve "more with less," using fewer resources per broiler compared to a decade ago. Cumulatively, however, environmental impacts have increased. As one researcher observes, the U.S. broiler industry "has largely optimized production economics," but "there are significant opportunities to improve environmental sustainability."[2]

This report aims to provide BCC-committed companies an overview of specific, quantified, and scientifically validated strategies that improve the environmental performance of U.S. broiler production, thus offsetting certain BCC requirements that would otherwise increase the carbon footprint of their broiler supply. Drawing on peer-reviewed literature, this report describes practices, techniques, and technologies — collectively, interventions — that translate to quantifiable decreases in GHG emissions per kilogram of live broiler.

Three categories of interventions are presented: (1) upstream interventions related to feed composition; (2) on-farm interventions related to energy, infrastructure, technology, and litter management; and (3) downstream interventions related to consumer preference and culinary strategy. Concurrently, we highlight instances where higher welfare practices may enhance these interventions. For example, higher welfare breeds may require less dietary protein, which complements efforts to reduce the carbon intensity of broiler feed, while controlled atmosphere stunning reduces water use during slaughter.

This report also addresses, with varying degrees of comprehensiveness, a related set of questions: How “sustainable” is the current U.S. broiler industry, and in what ways does the Better Chicken Commitment impact its ability to decarbonize further? To what extent will the BCC support or challenge organizations’ Scope 3 emissions reduction targets? What innovations in conventional broiler production can ensure that the BCC aligns with stakeholders’ decarbonization and resource efficiency goals with respect to waste, water use, and land use?

Table 1. Upstream, on-farm and downstream interventions reviewed

	Intervention	Impact	Study
Upstream	Agriculture: "sustainable" corn	19% decrease in kg CO2e/GHGe per kg live weight	Beal et al. (2023).
	Feed composition: food waste	7% decrease in FCR*	Dao et al. (2023).
	Feed composition: XAP enzyme	5%-9% decrease in GHGe per qty of broiler meat	Bundgaard et al. (2014).
On-Farm	Solar power & biodiesel	18% decrease in GHGe per kg live weight	Beal et al. (2023).
	Incinerating litter for heat	15% decrease in GHGe per kg live weight	Ogino et al. (2021).
	High-temperature sprinkler cooling (in lieu of cool-cell systems)	2% decrease in GHGe per kg live weight	Beal et al. (2023).
		65% decrease water consumption per kg live weight	Beal et al. (2023).
		3% improvement in FCR	Beal et al. (2023).
	Heat exchanger	3% decrease in GHGe per 1000 kg expected carcass weight	Leinonen et al. (2014).
Downstream	Demand shift to dark meat	Not yet quantified within the parameters of this report (U.S. broiler production)	N/A
	Demand mitigation	Not yet quantified within the parameters of this report (U.S. broiler production)	Rust et al. (2020).

In asserting that environmental impact and welfare can be improved in tandem, we take a systems-level approach that considers the production system as an integrated whole. This is because modifying one aspect of broiler production to optimize welfare may increase environmental impacts elsewhere. These, in turn, can be offset in various ways. For example, slower-growing breeds (chickens with growth rates of less than 50 grams per day) have higher welfare outcomes but require larger quantities of feed, which increases feed-related, upstream emissions. On the other hand, slower-growing breeds have lower mortality levels, wasting fewer inputs and avoiding upstream emissions. Moreover, proactive changes to the production system, like switching to cheaper, renewable energy sources, can further reduce indirect, Scope 2 emissions from purchased electricity and produce economic co-benefits.

Certain producers have already implemented this systems-level approach to achieve higher welfare and sustainability outcomes in tandem. Most notably, the Norwegian producer Norsk-Kylling decreased Scope 1 and 2 emissions more than enough to offset increases in Scope 3 emissions arising from its switch to a slower-growing breed.[3] Several peer-reviewed studies quantify the costs and benefits of systems-level approaches using life cycle assessment and techno-economic analysis. One researcher concludes that measures taken to improve welfare "have had no major effect on the efficiency of the system," and new technologies "can actually improve both the economic and environmental sustainability of such systems, in addition to improving welfare."[4]

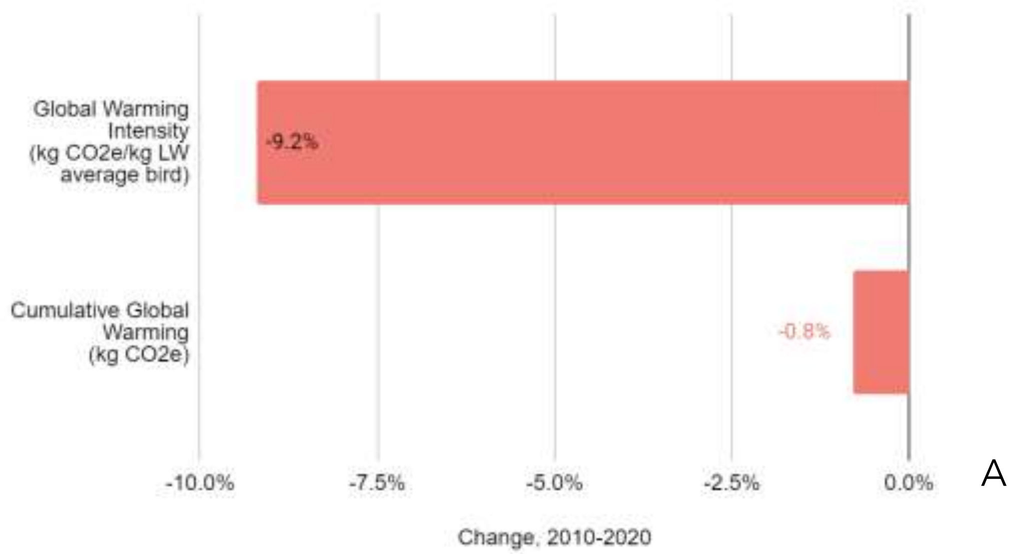
2. Establishing a baseline: The environmental impact of U.S. broiler production

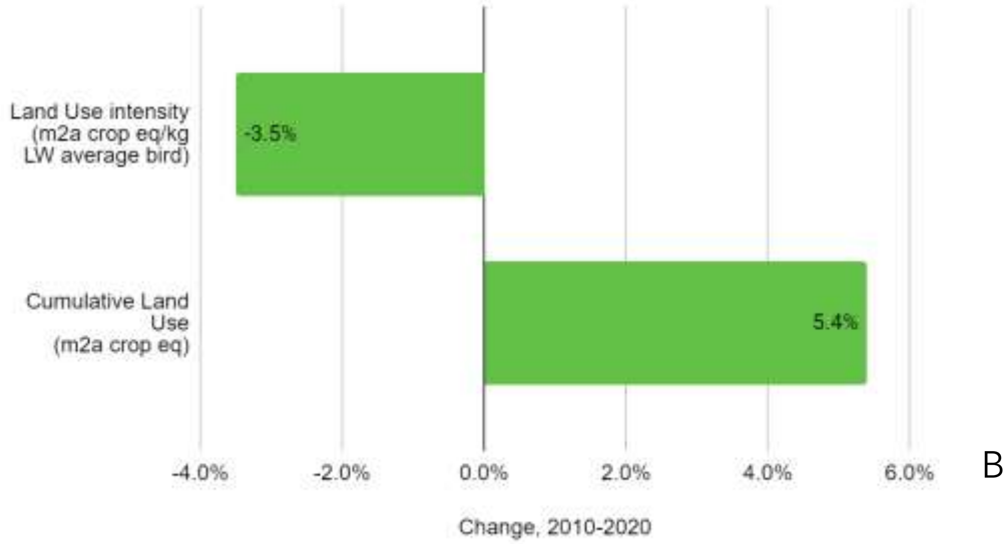
2a. Production increases have outpaced improvements in emissions intensity

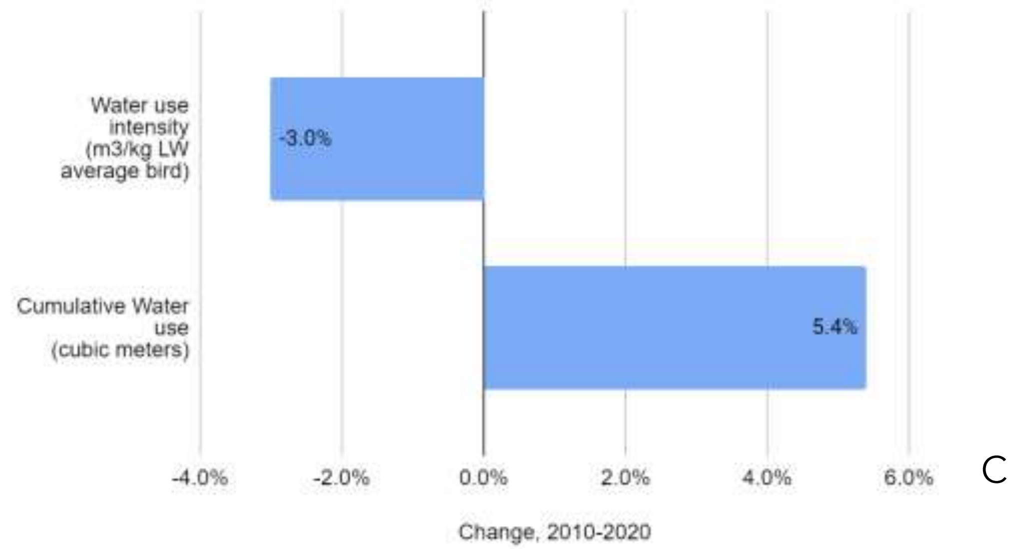
When considering the environmental impacts of higher welfare methods, it is useful to establish a baseline understanding of the U.S. broiler industry's current carbon footprint. In the decade ending 2020, the carbon footprint of the "average" broiler (a designation encompassing broilers and cull breeder hens) fell 9.2%.[5] In other words, the industry's *emissions intensity,* defined as emissions per unit of output, decreased. However, increases in production over the same period resulted in cumulative greenhouse gas emissions declining far less – only 0.8%, according to a third-party life cycle assessment published by the National Chicken Council.[6]

In a discussion of these calculations, the authors note that this performance falls short of being "fully sustainable". Improvements in emissions intensity "must keep pace with the rate of increase in overall production," they note. Another assessment of U.S. poultry production published in *Poultry* Science in 2023 offers a similar conclusion: "Although the US broiler industry has largely optimized production economics, there are significant opportunities to improve environmental sustainability."[7] Going forward, the challenge for producers is to enhance sustainability in tandem with welfare. The nature of that challenge, and the interventions available to address it, are discussed below.

Figure 1. Changes in (a) global warming intensity and cumulative global warming, (b) land use intensity and cumulative land use, (c) water use intensity and cumulative water use by U.S broiler sector, 2010-2020*







*LW (*live poultry weight)* refers to 1 kilogram of an "average" bird (broiler plus cull breeder hen)
Adapted from Thoma, G, and Putnam, B. (2020) Broiler Production System Life Cycle Assessment: 2020 Update. National Chicken Council

2b. Nature-related risks must be considered alongside climate risk

This report considers the environmental impact of broiler production through the lens of greenhouse gas emissions, for two reasons. First, it is imperative that the food and agriculture sector achieve emissions reductions. It will be impossible to halve global emissions by 2030, in line with the Paris Agreement, without transforming farming and consumption practices. Second, a common metric is needed to fulfill the purpose of this report — quantifying and comparing interventions that reduce the environmental impact of higher welfare broiler production. Greenhouse gas emissions, measured in kilograms of carbon dioxide equivalent (kg CO_2e), serve this purpose well.

While focusing on atmospheric emissions, we acknowledge the importance of other environmental impact metrics. The Task Force on Nature-Related Financial Disclosures (TNFD) calls on companies to consider nature as a whole — not just climate change — when evaluating their operational, reputational, and financial risks. The TNFD conceives of nature as four interrelated realms — land, ocean, freshwater and atmosphere — and urges companies to monitor and manage their impacts and dependencies on them all.[8]

Modern poultry production's impacts on nature are well-understood. Land use and water use by the U.S. broiler industry each increased 5.4% between 2010-2020, driven by increased production volumes.[9] A review of the environmental and human health impacts of intensive poultry farming published in 2023 highlights the "serious threat" posed by poultry litter and manure, which contain "pesticide residues, microorganisms, pathogens, antibiotics, hormones, metals, macronutrients (at improper ratios) and other pollutants" that can contaminate air, soil, and water and propagate drug-resistant pathogens.[10]

Higher welfare production can mitigate certain nature-related impacts. For example, controlled atmosphere stunning uses no water to process birds, whereas conventional water bath slaughter methods require more than 2,000 gallons per day (see Section 6). Additionally, welfare-focused producers may be less dependent on antibiotics. Among slow-growing broiler flocks in The Netherlands, 91-94% did not receive antibiotics, versus 67-72% of conventional fast-growing flocks, according to data collected between 2014 and 2018.[11,*] In other cases, higher welfare production can magnify nature-related impacts and risks — by requiring more feed and land, for example — but these can and should be managed with the interventions discussed in this report.

2c. We estimate a 9-16% "emissions gap" between conventional and higher welfare U.S. broiler production, absent mitigations

The carbon footprint of U.S. broiler production is 2.89 kg CO_2e per kilogram live weight of broiler and culled breeder hen, based on calculations published in 2020 by the National Chicken Council that assume a final weight of 6.37 pounds, a mortality rate of 7.15%, the use of fossil fuels for heat and electricity, and a diet consisting of 59% corn and 25% soybean meal.[12,13] Other life cycle assessments of U.S. broiler production provide estimates that are 30-40% higher, indicating a range of 3.8 - 4.03 kg CO_2e.[14,15]

[*] The Global Animal Partnership (GAP) certification prohibits the use of antibiotics, and broiler breeds approved by GAP meet the requirements of the Better Chicken Commitment.

We define the *theoretical emissions gap* as the incremental emissions from BCC-compliant broiler production in the absence of offsetting measures. Quantifying the emissions gap is difficult, given the scarcity of peer-reviewed, publicly available life cycle assessments that compare BCC-approved breeds with conventional broilers within U.S. production parameters. Based on available data, the emissions gap is roughly 9-16%.

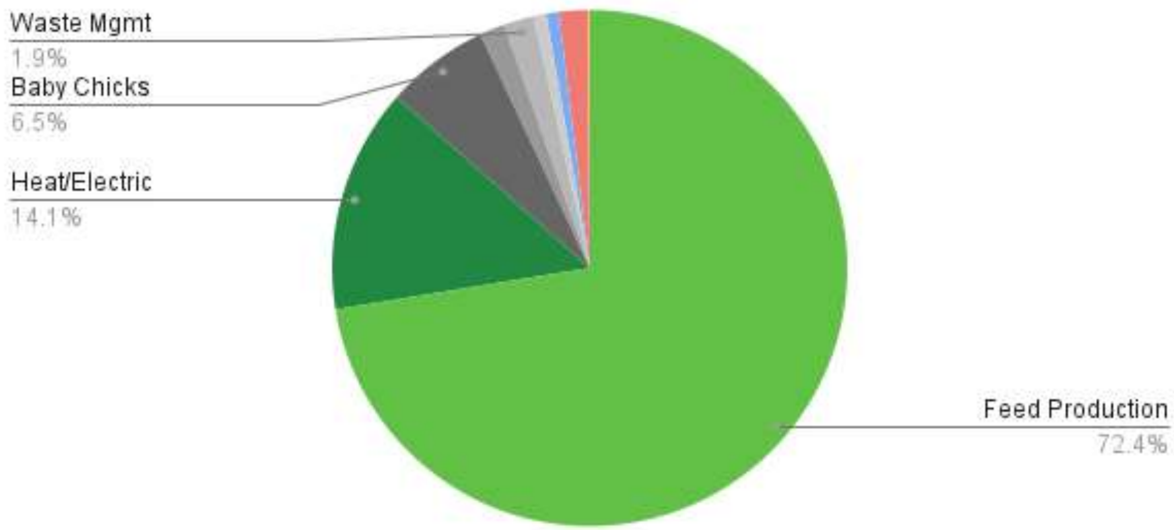
We base this range on two studies. First, a cradle-to-farm-gate assessment comparing Aviagen Ross 308 broilers with the BCC-approved Aviagen Ranger Classic found that emissions per kilogram of live weight were 16% higher in the Ranger Classic (1.49 kg CO_2e versus 1.29 kg CO_2e), driven by higher feed consumption and electricity use per kilogram of live weight.[16,†] Second, Perdue in 2022 trialed the BCC-approved Hubbard Redbro and performed a comparative life cycle assessment versus two conventional breeds, the Ross 308 and the Cobb-Vantress Cobb 500. It concluded that the climate-change impacts of the slower-growing Redbro were 9% higher when it was given the same feed as the fast-growing broilers.[17] When the Redbro was given a "lower-protein feed," its climate change impacts were reduced by 1.5%.[18]

It is feed, more than any other factor, that drives the emissions gap between conventional and BCC-compliant broiler production. The production and processing of feed accounts for nearly 70% of the carbon footprint of broiler production.[19] Moreover, slower-growing breeds require higher quantities of feed per bird given that they exhibit lower feed conversion ratios and have longer lives. Therefore, feed-related mitigations are paramount and will be discussed later in this report.

† These estimates exclude land-use-change (LUC) emissions and are thus relevant to U.S. production, where LUC is not material to broiler production. The role of LUC emissions in broiler feed is explained later in this report.

Figure 2. Feed is main driver of broiler production's global warming impact

% of total greenhouse gas emissions per kilogram of live weight for slaughter



Source: Thoma, G, and Putnam, B. (2020) Broiler Production System Life Cycle Assessment: 2020 Update. National Chicken Council

3. Upstream and on-farm strategies can eliminate or narrow the emissions gap

Both anecdotal evidence and quantitative analyses suggest that an emissions gap of this size can be minimized or even eliminated in a U.S. broiler operation through on-farm measures. A sustainability assessment of U.S. broiler production published in 2023 calculates that substituting fossil-based energy with renewable sources – that is, reducing a farm's Scope 1 and Scope 2 emissions – can decrease emissions per kilogram of live weight by 18%.[20] In Norway, the poultry producer Norsk-Kylling reduced direct and indirect energy-related emissions by 26%, and 53%, respectively, which more than offset a 3% increase in upstream emissions related to their switch to a slower-growing breed.[21]

Tackling upstream, Scope 3 emissions related to feed production more than doubles the GHG reduction potential. The aforementioned U.S. study estimates that emissions fall 38% per kilogram of live weight when on-farm interventions are combined with upstream, feed-related interventions as follows: installing solar energy for electricity and heat; using biodiesel instead of diesel for transport, backup generators, and equipment; utilizing large-droplet sprinkler systems for cooling instead of cool-cells; and substituting sustainably grown corn in feed. Together, these measures reduce upstream, feed-related impacts, lower on-farm emissions, and improve the efficiency with which broilers convert feed to weight.[22,§]

4. Lower mortality in slower-growing breeds is an inherent "sustainability benefit" when combined with other mitigation strategies

Slower-growing breeds have an inherent "sustainability benefit" in the form of lower mortality. One study found that total mortality of fast-growing breeds was 6.2% versus 2.6% in slower-growing strains on commercial farms, while another study found that the average mortality of the three most common conventional breeds – the Ross 308, Cobb 500, and Hubbard Flex – was almost twice that of the slower growing JA757.[23,24]

According to statistics published by the National Chicken Council, the mortality rate of U.S. broilers in 2022 was 5.3%, the highest since 1965.[25,††] That implies a pre-slaughter loss of more than 500 million broilers annually in the U.S., based on an annual production volume of 9.1 billion birds. This waste of life is accompanied by waste of feed, water, energy, and labor inputs.[§§]

[§] In this scenario, other resource metrics improve as well: Water depletion, energy demand, eutrophication, and respiratory effects are reduced by 83%, 41%, 38%, and 33%, respectively. Separately, these changes are accompanied by an increase in operating costs of 8%, though the authors note that this may be offset in two ways: by charging price premiums on the basis that the product is sustainably produced, and by seeking new revenue streams from GHG reduction credits.

[††] In addition, U.S. broilers are the heaviest they've ever been, averaging 6.56 pounds (based on live weight) as of 2022.

[§§] In a conventional U.S. broiler system, higher mortality rates in heavier birds contribute to a 12% increase in operating costs per kilogram of live weight, reduce annual yields of broiler live meat by 5.5%, and reduce the 30-year net-present-value of the broiler system by 4%, according to one analysis, though the costs are offset by the higher prices that heavier birds command (Beal et al. 2023). However, a more favorable outcome for humans and animals alike would be a broiler system where fewer birds die before slaughter, and higher price premiums reflect more sustainable production methods.

4a. Choose "intermediate growing" BCC-approved breeds when optimizing for welfare and emissions

The lower mortality rates of slower-growing breeds must be considered against a countervailing factor: they have lower slaughter weights and lower yields of white breast meat. As a result, higher welfare broiler production requires more feed, housing, water and transport resources to maintain current production volumes. In the United States, there is an additional challenge: Americans have traditionally favored white meat over dark meat, influenced by marketing campaigns that promoted the former. Thus, it is difficult to compensate for lower white meat yields by simply offering more dark meat to the market.

While it is true that higher welfare breeds' lower yields of white meat necessitate more upstream and on-farm inputs, the calculations that underlie this logic may be exaggerated. One informal analysis covered by an industry newsletter[26] indicates that the breast meat yield of a slow-growing, five-pound Red Ranger carcass is 11 percentage points lower than that of a fast-growing Cornish Cross – 20.3% versus 31.2%.[27]

However, this calculation requires two prominent caveats: First, the Red Ranger is among the slowest growing of the higher welfare breeds available today, with a growth rate of 39.6 grams per day, and typically it is not used on commercial farms. Thus, the Red Ranger is not the most useful basis for comparison when evaluating the difference between breast meat yields in slow-growing and conventional broilers for large-scale production. Second, "Cornish Cross" is a generic term encompassing several breeds of chicken that are raised for meat, whose growth rates and carcass yields can vary widely. This also limits the usefulness of the analysis.

Consider instead the Hubbard Redbro, an "intermediate-growing" BCC-approved breed that has a faster cumulative growth rate of 51.5 grams per day, at a final live weight of approximately five pounds.[28] When the Hubbard Redbro is compared with the Ross 308 – one of the most widely used commercial broiler breeds that averages 64 grams per day in body weight gain[29] – the difference in breast meat yields narrows to 4.7 percentage points (20.6% for the Hubbard Redbro versus 25.3% for the Ross 308 (based on as-hatched data and final weights of approximately five pounds).[30] Thus, when optimizing both welfare and environmental sustainability – not to mention economic viability – it is important to select those BCC-approved broilers with relatively faster growth rates – otherwise known as "intermediate-growing" breeds.

4b. Defining "fast-growing," "slower-growing," and "intermediate-growing" broiler breeds

The *fast-growing breeds* widely used in today's broiler industry grow an average of 65 grams per day compared to slower-growing breeds, which have average growth rates of approximately 50 grams per day or less. Within the category of slower-growing breeds, "intermediate-growing" is used to further classify those BCC-approved breeds that have improved welfare outcomes (including better leg health, survivability, and expression of natural behaviors) while maintaining average growth rates of approximately 46-50 grams per day. This enhances their commercial appeal for broiler producers. Examples of intermediate-growing BCC-approved breeds include the Hubbard Redbro, Hubbard JA787, and Aviagen Ranger Classic.

Table 2. Average growth rates of fast and slower-growing broiler breeds

	Fast Growing Breeds	Slower-Growing Breeds
Average growth rate	65 grams / day	Slow-growing: ≤ 50 grams / day Intermediate-growing: 46-50 grams /day

4c. Demand shifting to dark meat may increase producers' receptivity to higher-welfare breeds by improving production economics

Proactive measures to promote consumption of dark meat (i.e., leg and thigh meat) can improve producers' receptivity to slower-growing breeds by improving the economics of production. U.S. producers have signaled that consumers' preference for breast meat is an impediment to trialing slower-growing breeds, as the higher costs of BCC-compliant production cannot be recouped on the white meat yield alone.[31]

"To increase U.S. consumption of dark poultry meat is possible," writes a team of professors at the University of Arkansas Department of Food Science.[32] Advertising that highlights the low fat content of white meat, suggesting it is the healthiest part of the chicken, “may have been a mistake,” and now needs to "promote all parts of a chicken as being healthy.”[33] Roasted, skinless chicken thigh contains nearly triple the amount of zinc, more than double the amount of iron, and 17% more riboflavin (one of the eight B vitamins) than skinless chicken breast per 3.5-ounce (100-gram) serving.[34,35] It contains 24.8 grams of protein per serving — seven fewer grams than chicken breast, but still 50% of the recommended daily value for U.S. adults.[36] Conversely, skinless thigh meat contains 1.3 additional grams of saturated fat and 17 additional milligrams of cholesterol[37,38] — though its richer flavor profile is generally perceived to be more satiating. There are also indications that higher-welfare broilers offer nutritional advantages. For example, meat from intermediate-growing, higher welfare breeds can contain 10%-30% less fat than fast-growing breeds and higher proportions of omega-3 fatty acids, long-chain omega-3 fatty acids, Vitamin E, and iron.[39]

Greater consumer awareness of the nutritional benefits of dark meat could make it easier for retailers to market and sell it, giving it equal prominence on refrigerated shelves and at meat counters. In turn, higher consumer demand for dark meat could increase producers’ receptivity to higher welfare breeds with lower white meat yields. This has occurred in The Netherlands, where grocery stores display dark meat with the same prominence as breast meat after a nationwide adoption of higher welfare standards.[40] It is important to note that for some suppliers, dark meat processing may require capital investment — for example, in the form of deboning equipment. Therefore, clear demand signals from retailers and consumers will be necessary to promote this shift.

These demand signals are strengthening. Dark meat has enjoyed increased popularity in the past two decades amid ethnic and demographic shifts in the U.S. population that have brought new culinary preferences to light. Since 2000, dark meat’s share of the total dollar value of a broiler chicken has risen from 12% to nearly 30%, driven by chicken legs. Meanwhile, chicken breast’s share of value has dropped from 66% to 45%, according to one analysis.[41] (Wing meat accounts for the remainder.) Brands can facilitate this trend by featuring dark meat cuts on their menus, emphasizing its richer flavor and nutritional content.

4d. Demand mitigation is a credible strategy that complements welfare commitments

Like the other strategies reviewed in this paper to offset the carbon footprint of chicken production, demand mitigation can make higher-welfare production even more viable from an environmental standpoint and produce economic co-benefits for both brands and consumers. U.S. chicken consumption would need to fall 17.3% with the intermediate-growing Ranger Classic and 16.7% with the intermediate-growing Ranger Gold if these breeds were raised without increasing land use, according to a 2022 study.[42] (The calculations accounted for the land used by barns as well as crops grown for feed – i.e., direct and indirect land use.)

There is robust scholarship around the challenge of reducing meat overconsumption. One study proposes six types of interventions: Eliminating Choice, Restricting Choice, Fiscal (Dis)incentives, Changing Defaults, Providing Services, and Providing Information.[43] An example of *Eliminating Choice* is the introduction of no-meat days in office or school cafeterias. *Restricting Choice* is a substitution strategy where meat is substituted with another high-nutrient option like beans. *Fiscal incentives and disincentives* take the form of taxes or price changes for meat-containing items. *Changing Defaults* calls for changing the placement of vegetarian meals on menus.

Organizations researching related strategies in real-world settings include Sodexo's Future Food Collective, Google's Food Program, and Stanford University's Food Institute. Sodexo's Future Food Collective has researched menu names for plant-based dishes, examining their impact on guests' purchasing intent and choices. The Google Food Program worked with the nonprofit organization Food for Climate League "to evaluate ways to title and describe menu items in order to drive climate-smart dish choice".[44,45] At Stanford University, an effort is underway to reduce food-related greenhouse gas emissions from student dining by 25% by 2030 through "plant-forward shifts" in dining programs and sourcing.[46] In partnership with the Stanford Food Institute, this initiative targets 25% reductions in poultry and pork consumption and 33% reductions in beef, dairy, and egg consumption. The program's strategy consists of six focus areas – Menu Mix, Defaults, Portions, Placement, Presentation, Promotions and Prompts – which are summarized below:

- The **menu mix** favors seafood, legumes, nuts, seeds and grains.
- Menu **defaults** present a "typical" meal as one featuring meat, poultry, eggs, and dairy as side items and/or by-request-only items, treating meat as a condiment.
- **Portion sizes** for meat in composed dishes are no more than 3 ounces per serving for beef, pork, or poultry, and sourcing practices favor smaller, bone-in cuts of meat.
- **Placement** of menu items favors plant-based options, which are presented first along the serving line.
- **Presentation** focuses on making vegetables, beans, whole grains and other plant-based dishes look as delicious and enticing as possible.

- **Messaging and prompts** in menu labels and promotions emphasize the sustainability attributes of dishes and use "taste-focused language" to underscore how "flavorful, fun, and delicious" plant-based eating can be.[47]

Case study: Achieving higher welfare outcomes without increasing GHG emissions

The example of the Norwegian broiler producer Norsk-Kylling shows that it is possible to achieve higher-welfare outcomes without a concomitant increase in GHG emissions by applying a systems-level approach.

In 2018, Norsk-Kylling transitioned from Ross 308 chickens to the slower-growing Hubbard JA787 breed. The company reports the overall carbon footprint of the JA787 is 1% lower than their previous faster growing breed. This is due to a combination of inherent benefits and proactive system changes including:

- 40% decrease in daily mortality during grow-out[48]
- 70% decrease in overall bird condemnation rates (0.65% JA787 vs. 2.17% Ross 308)[49]
- 26% decrease in carcass waste at slaughterhouse due to 76% reduction in mortality during transport and fewer myopathy-related carcass rejections[50]
- Decreased proportion of soy in feed from 50% to 10%[51]
- Use of renewable energy throughout the operation[52]

The Norsk-Kylling case is relevant to U.S. broiler production insofar as it shows the decreased morality rates and reduced carcass waste resulting from higher welfare breeds. It is less relevant to U.S. producers where feed is concerned – while NK achieved emissions reductions by moving away from deforestation-linked soy, the carbon footprint of soybean meal in the U.S. is a fraction of Europe's: 0.40 kg CO_2e/kg versus 3.05 kg CO_2e/kg in the UK.[53] With that said, the example of NK shows starkly that higher welfare, longer-lived breeds do not spell an inevitable rise in carbon emissions.

5. GHG mitigation strategies for feed, energy, and litter

In this section, we focus on interventions to reduce the carbon footprint of broiler production, starting with feed-related strategies. In some cases, these interventions apply equally well across conventional and higher welfare production. Our intention in showcasing these interventions is to provide further avenues for offsetting the higher feed and resource requirements of slower-growing breeds.

5a. Reducing feed-related impacts: important considerations

When considering feed-related interventions, it is important to differentiate between U.S. and European broiler production when reviewing strategies to reduce the emissions of broiler feed. Several scientific studies indicate that it is possible to achieve significant decreases in emissions by reformulating feed to contain lower quantities of key ingredients like soy while retaining key nutritional attributes. These studies are more applicable to European than U.S. production because the carbon footprint of soy is higher for European producers, who are traditionally reliant on soy imported from Brazil.[54] The U.S. broiler industry relies on domestically produced soy.

In South American soy production, emissions from land-use change (LUC) are the main contributor to the crop's carbon footprint.[55] In contrast, U.S.-produced soy has negligible LUC emissions and a smaller emissions profile overall. Thus, the benefits of certain feed interventions are larger for European producers than their U.S. counterparts, insofar as they relate to land-use change.

In U.S. feed production, two mechanisms for reducing emissions are (1) achieving the lowest possible feed conversion ratio for a given target broiler weight, thus minimizing quantities of feed used; and (2) decreasing the base carbon footprint of feed ingredients through measures such as low-carbon farming, lower nutrient density, and alternative ingredients.

5b. Enzymatic feed interventions

One area of study focuses on the role of enzymes in reducing feed-related emissions. An example is the enzyme product known as "XAP," which is a combination of xylanase (X), α-amylase (A), and protease (P). XAP works to improve digestibility, thus reducing the amounts of corn, soybeans, fats, and other feed ingredients needed to achieve nutritional outcomes. Feed trials using XAP showed a 3.0%-5.5% reduction in feed quantity used to rear the same amount of broiler meat.[56]

As a result, in a peer-reviewed life cycle assessment, XAP delivered net GHG reductions in the range of 6 g to 345 g CO_2e per kilogram of live broiler. The exact reduction achieved depended on two parameters: the impact of land-use change (LUC) emissions and the amount of XAP used in the feed formulation. Where the burdens of LUC were negligible – as in U.S. broiler production — the GHG benefits of XAP were on the low end of the range. The GHG reduction benefits were maximized when the burden of LUC was material (as in European broiler feed) and the amount of XAP used in the feed formulation was increased (though doing so reduced the fat content assumed necessary to maintain pellet quality).[57] By partially displacing expensive feed ingredients, XAP reduced the price of feed by 1.3%, or $4.04 per ton of feed, according to the same study.

5c. Use of food waste in feed

The use of food waste in broiler feed can reduce carbon emissions via three mechanisms: (1) displacing food in landfills, which is a potent source of methane; (2) reducing quantities of conventional feed ingredients; and (3) improving feed conversion ratios (FCRs). This practice can lower GHG emissions from broiler production by as much as 25%, according to one study.[58]

The use of food waste in animal feed is an established practice. Broilers have been fed food waste at varying percentages, with significantly similar performance to conventional diets containing corn and soy. Documented types of food waste fed successfully to broilers include bakery goods, dried tomato puree, dried and ground carrot, carrot-tops hay, cornflakes waste, oyster mushroom waste, meat meal, and leftover Korean food.[59] In Japan and South Korea, 40-46% of food waste is recycled as poultry feed.[60] In the US, approximately 85% of food waste generated in the food manufacturing and processing sector was repurposed for animal feed, mostly for swine and cattle, according to a 2013 survey of manufacturing companies.[61]

Animal feed made with food waste has been shown to improve feed efficiency. A 2023 study evaluated the performance of Hy-Line Brown laying hens on a 100% food waste-based diet and found that hens had a 6.7% lower FCR at 24-43 weeks of age than those fed conventional diets.[62] The birds were fed an experimental diet containing food waste sourced from breweries, hospitals, nursing homes, bakeries, pubs, restaurants, abattoirs, fish processing facilities, and fruit and vegetable markets. Each food waste stream was processed into a granular powder and blended into a complete mash feed.[***] (The processing was performed by Food Recycle Ltd., an Australia-based company converting commercial food waste into high-performance animal feeds. Other U.S. companies processing food waste into poultry feed include Wilenta and Mill.[†††]

[***] Composition of the experimental and control diets is shown in a table accessible at https://www.nature.com/articles/s41598-023-34878-2/tables/3.

[†††] Mill sells composting bins to households and collects dehydrated food waste, with the intention of processing it into ingredients for chicken feed. For more information about Mill, see: https://www.mill.com/ and https://www.axios.com/2023/01/18/food-waste-mill

Converting food waste to dry animal feed outperformed composting on 11 out of 12 environmental and health impacts including greenhouse gas emissions, marine and terrestrial eutrophication, and acidification, according to the results of a life cycle assessment performed in 2017.[63,‡‡‡] (The study was performed on pig feed, due to the long-established practice of feeding recycled food waste to these animals, but the authors affirmed that food waste can also be fed to poultry, fish, and ruminants.) When landfilled, one ton of food waste has five times the global warming potential of food waste recycled into dry animal feed.[64] Thus, recycling food waste into animal feed can reduce the Scope 3, waste-related emissions of food processing or manufacturing companies that engage in this practice in lieu of composting or landfilling, as well as the Scope 3, supply chain emissions of brands that purchase from such companies.

Kipster's Circular Chicken Feed

Kipster, a poultry farm operator with operations in the United States and The Netherlands, is a compelling proof-of-concept for chicken feed that incorporates surplus food produced for, and otherwise wasted by, humans. Kipster feeds both its hens and roosters — which it raises for meat — a "circular feed" whose carbon footprint is approximately half that of conventional chicken feed, according to the company's annual report.[65] Kipster uses byproducts from commercial pasta makers for its feed, with the explicitly stated goal of bypassing the use of agricultural land.

5d. Sustainably produced corn

Corn accounts for more than 40% of the feed-related emissions of U.S. broiler production.[66] Substituting "sustainable" corn for conventionally produced corn in feed reduces emissions per kilogram of live broiler weight by 19%, one life cycle analysis found.[67,§§§] In this context, sustainable corn is defined as corn produced without

‡‡‡ In the same study, converting food waste into animal feed had a *larger* global warming impact than anaerobic digestion, in which food scraps are "shredded, sieved, and sent to a digestion tank." Still, converting food waste to animal feed had a smaller impact than anaerobic digestion overall, outperforming on 10 out of 12 health and environmental impact categories. It should be noted that manufacturing dry feed – as opposed to wet feed – requires additional heat and energy, which contributes to its carbon footprint.

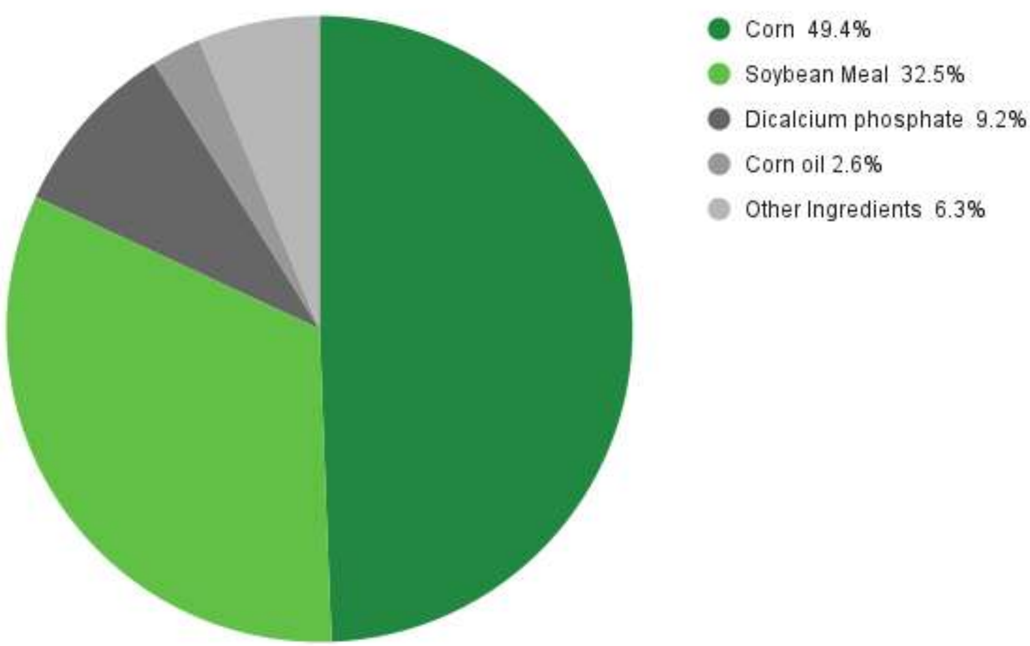
§§§ The impact of non-irrigation methods on crop yields is an important, though context-dependent, consideration when assessing GHGe impacts. A life cycle analysis conducted on irrigated corn and non-irrigated wheat in Spain concluded that the carbon footprint of one hectare of irrigated corn was higher. But when the irrigated corn's "higher productivity" versus non-irrigated wheat was considered (14,000 kg/ha-year vs. 1500 kg/ha-year), emissions per kilogram of corn decreased and ultimately "favored" this crop. (See Abrahão, R., Carvalho, M. & Causapé, J. Carbon and water footprints of irrigated corn and non-irrigated wheat in Northeast Spain. Environ Sci Pollut Res 24, 5647–5653 (2017). https://doi.org/10.1007/s11356-016-8322-5).

irrigation, with 50% less synthetic fertilizer, lime, herbicide and insecticide than conventional corn, and produced on farms that use biodiesel instead of conventional diesel.

Sustainable corn also reduces water depletion potential by 82% and eutrophication (driven by nitrogen fertilizer) by 37%. On the other hand, sustainable corn is estimated to increase land use by 8% due to 25% lower yields, and results in an $0.08-per-kilogram increase in corn costs.[68]

Figure 3. Corn and soybean meal are the main drivers of GHG emissions in broiler feed

Contribution to feed-related emissions by feed ingredient



Source: Colin M. Beal, David M. Robinson, Jack Smith, Léda Gerber Van Doren, George T. Tabler, Samuel J. Rochell, Michael T. Kidd, Walter G. Bottje, Xingen Lei, Economic and environmental assessment of U.S. broiler production: opportunities to improve sustainability, Poultry Science, Volume 102, Issue 10, 2023, 102887, ISSN 0032-5791, https://doi.org/10.1016/j.psj.2023.102887

5e. Renewable Energy, Biofuels, and Other Efficiency Strategies

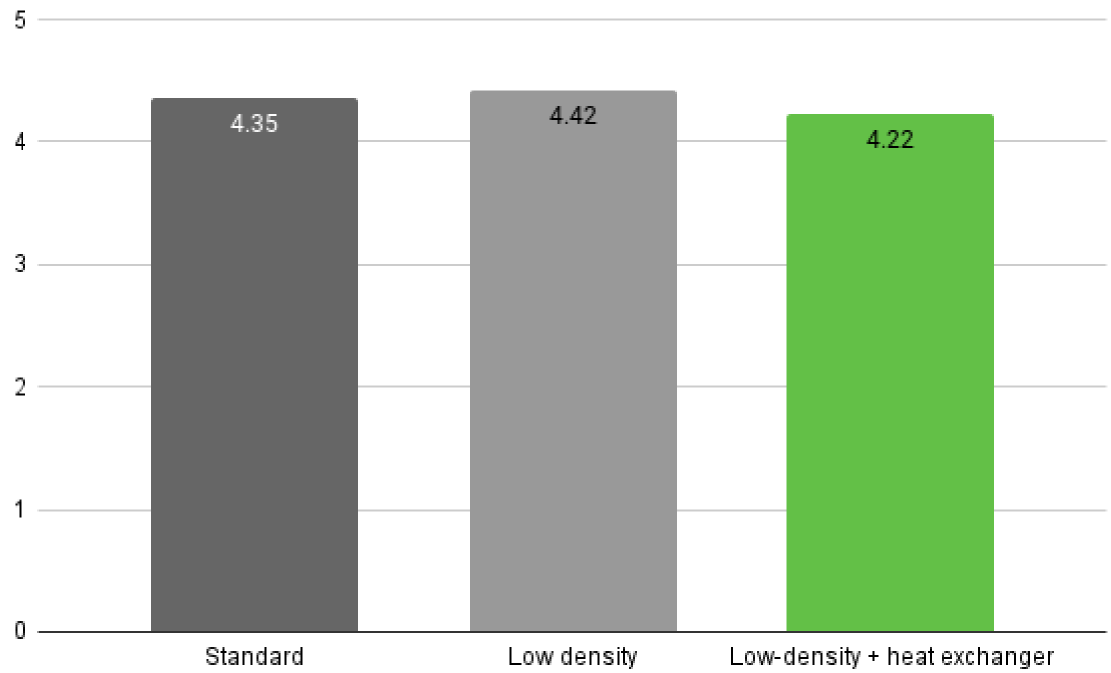
Heat and electricity are the second-largest contributors to U.S. poultry emissions, accounting for approximately 11.4% of global warming impacts. Renewable energy and biodiesel can reduce operating costs and environmental impacts. According to one analysis, the use of solar power for electricity and heat, and biodiesel in lieu of conventional diesel, reduce production costs by $0.002 per kilogram of live weight (assuming community-scale solar power costs of $0.021/MJ) and carbon emissions by 18%, per kilogram of live weight.[69] In Sweden, GHG emissions per kilogram of broiler meat decreased by 24% in the 15-year period from 1990-2005, driven primarily by the use of bio-fuels instead of oil for heating chicken houses. Emissions per kilogram of carcass weight fell from 2.5 to 1.9 kg CO_2e.[70]

The lower stocking density requirements of the Better Chicken Commitment may increase the amount of fuel needed to heat indoor broiler systems during the brooding period for young chicks or during periods of colder outside temperatures, because fewer birds in the same space produce less heat. According to one study that modeled the setup of a typical UK chicken house, reducing the stocking density from 7.6 to 6.1 pounds per square foot (37 to 30 kg/m^2) led to a 1.6% increase in greenhouse gas emissions per kilogram of broiler meat produced. However, the global warming potential of the lower-density system *decreased* by 3% when combined with a heat exchanger to reduce energy loss with ventilation air.[71] "The results suggest that welfare-friendly changes in chicken systems can be achieved without a compromise in their environmental impacts," the study concluded.[72]

Given that most U.S. chickens are grown in the warmer year-round climates of the southern states, the decrease in global warming potential from the use of heat exchangers, may be lower than that modeled for a U.K. broiler house. However, even in warmer U.S. climates, supplementary heating is required to achieve the higher temperatures needed to brood young chicks and help remove excess humidity accumulation during the first three weeks of age. Therefore, this mitigation approach is still worthy of consideration within U.S. production systems.

Figure 4. Use of heat exchanger in low-density broiler systems reduced overall carbon footprint versus conventional housing

Global warming potential (kg CO_2e per kg live weight)



Source: I. Leinonen, A.G. Williams, I. Kyriazakis, The effects of welfare-enhancing system changes on the environmental impacts of broiler and egg production, Poultry Science, Volume 93, Issue 2, 2014, Pages 256-266, ISSN 0032-5791, https://doi.org/10.3382/ps.2013-03252.

Another promising intervention is the use of *high temperature sprinkler cooling*, in which broiler houses use large-drop sprinkler cooling systems instead of cool-cells to regulate bird temperature. This practice reduces water consumption by 65% and improves the feed-conversion ratio by 3.2% while raising barn temperature to 88°F, according to one analysis. This drives down feed costs, resulting in a reduction of operating costs by $0.02 per kilogram live weight and a decrease in greenhouse gas emissions of 2% versus conventional broiler houses.[73]

5f. Litter as Energy

Poultry litter comprises a mixture of manure and bedding materials including wood shavings, rice hulls, and peanut shells. It is often spread on land, posing adverse risks to soil, water, plant and human health, and increasing the risk of antibiotic resistance.

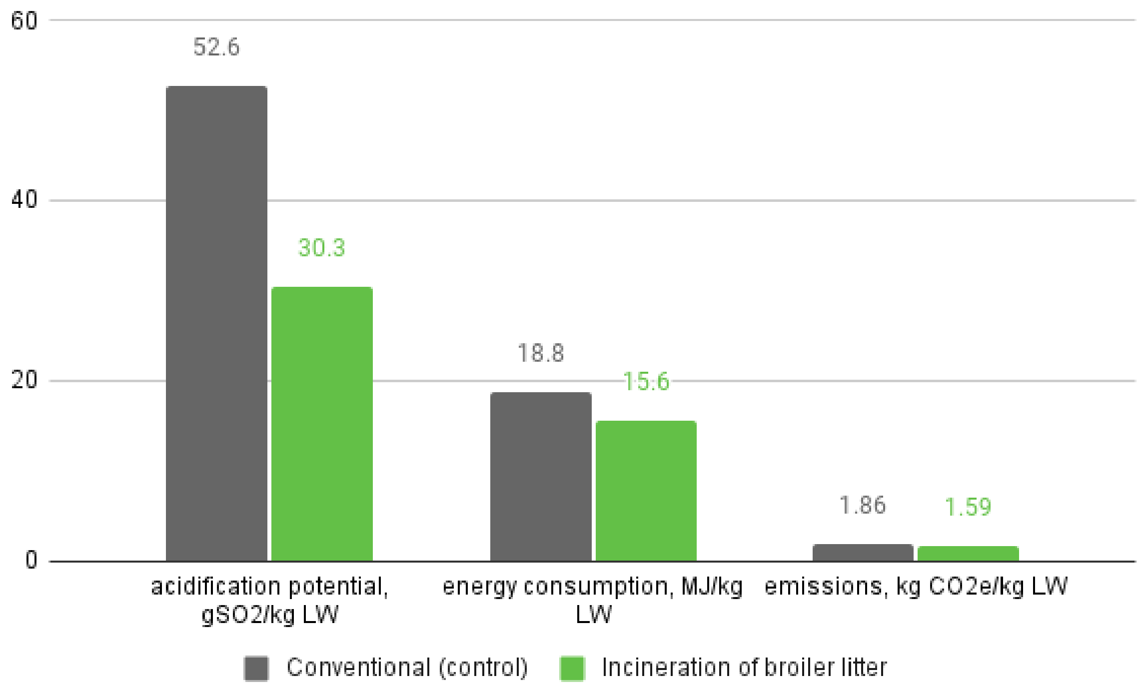
An alternative approach is incinerating litter for use as a heat or electricity source. This practice reduced heating-related fuel consumption by 80%, GHG emissions by 15%, energy consumption by 17%, and acidification potential by 42%, according to a life cycle assessment of broiler chicken production in Japan (see Figure 5).[74]

In the United States, Carolina Poultry Power (CPP) utilizes litter from local farms to power a combined heat and power (CHP) facility. Located in Farmville, North Carolina, CPP processes 240 tons of poultry litter per day, generating 12,300 MWh of electricity per year. The energy produced qualifies for Renewable Energy Credits (RECs), which enhances the economic viability of facilities like CPP.

Projects like CPP are supported by state legislation. In 2007, North Carolina adopted the Renewable Energy and Energy Efficiency Portfolio Standard (REPS), which requires 900,000 MWh of electricity derived from poultry waste annually. According to the U.S. Department of Energy, the facility provides valuable intelligence to farms and poultry integrators. "Farms and poultry integrators are notified when litter is unusually wet or untilled, which are leading indicators of potential biosecurity or poultry disease issues. In this way, CPP not only provides waste disposal to the industry, but also provides back-up check on clean poultry growing practices."[75]

Figure 5. Acidification, energy consumption, and emissions reductions from incinerating broiler litter

(LW = live weight)



Source: Ogino, A.; Oishi, K.; Setoguchi, A.; Osada, T. Life Cycle Assessment of Sustainable Broiler Production Systems: Effects of Low-Protein Diet and Litter Incineration. Agriculture 2021, 11, 921. https://doi.org/10.3390/agriculture11100921

6. Mitigating water-related risks with higher-welfare broiler production

As noted above, this report considers environmental sustainability through the lens of greenhouse gas emissions to facilitate comparability and uniformity when reviewing mitigations strategies. However, companies are exposed to other nature-related risks, and increasingly, they are called upon to measure and monitor risks and impacts related to nature's four domains: land, ocean, freshwater and atmosphere.

Freshwater is a highly relevant nature-related risk factor for poultry producers and purchasers. Water use in the U.S. poultry sector increased 5.4% between 2010 and 2020 before accounting for water use during slaughter.[76,****] The water intensity, or gallons of water per finished product, of two of the largest U.S. poultry producers – Tyson and Pilgrim's Pride – were 1.02 and 1.27, respectively, as of 2022, both up 6% since 2019.[77,78]

Controlled atmosphere stunning (CAS), the slaughter method required by the Better Chicken Commitment, requires no water during processing, in contrast to conventional methods that stun birds with an electric current that is run through a water bath.[79,††††] In a slaughter facility with a throughput capacity of 12,000 birds per hour, water bath stunning uses 2,376 gallons of water per day, according to a review of the E.U. slaughterhouse sector.[80] In CAS systems, water is used solely for the cleaning of equipment, such as transport crates, and consumes 924 gallons a day – 61% less – for this purpose, based on the same throughput. Conversely, CAS consumes more electricity than conventional water bath stunning, so renewable energy should be used where possible to offset incremental emissions.

While this report focuses on environmental impacts and animal welfare, it is worth noting that CAS is reported to improve worker satisfaction, given that it eliminates the need to handle birds directly.

7. Conclusion

This paper reviews several interventions that can narrow, and potentially eliminate, the theoretical emissions gap between conventional and higher welfare (BCC-compliant) broiler production, with a focus on the U.S. poultry industry. The incremental carbon emissions of BCC-compliant production require further analysis in the form of life cycle assessments that reflect U.S. production parameters. For this report, we rely on research indicating that the emissions gap is 9-16%,[81,82] and we identify interventions that can narrow or even eliminate this gap by reducing Scope 1, 2, and 3 emissions across the production system.

The production and processing of feed is the leading driver of poultry's carbon emissions, and the most effective mitigations are those that decrease the amount of

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**** Slaughter is rarely considered in life cycle assessments of broiler production, which tend to evaluate a kilogram of live weight ready for slaughter. Thus, the environmental impact of slaughter must be considered separately from upstream production, and emissions data for various slaughter methods do not appear in literature searches.

†††† In Controlled Atmosphere Stunning (CAS), birds are either stunned irreversibly or killed with the use of gases or mixtures of gases such as argon, nitrogen, and carbon dioxide.

feed consumed or replace certain feed ingredients with lower-impact alternatives. Peer-reviewed research indicates that the incorporation of sustainably produced corn, enzymes, and food waste into feed each reduces climate change impacts. Sustainable production is only possible if it is economically viable, and interventions like renewable energy, use of food waste in feed, and feed reformulation may reduce costs as well as environmental impacts.

When optimizing for welfare and emissions reduction, breed selection is an important consideration, as growth rates among BCC-approved broiler strains vary widely. As noted above, the Hubbard Redbro grows 30% faster than the Red Ranger (assuming a 5.3-pound final weight) which translates to smaller decreases in breast meat yields, lower GHG emissions and higher economic viability. Additional measures to improve the environmental and economic profile of higher welfare, intermediate- and slow-growing breeds include demand shifting to dark meat and demand mitigation toward plant-rich foods. The latter strategy is supported by a growing body of research.

To improve our understanding of the carbon footprint of higher welfare practices – particularly intermediate-growing, BCC-approved breeds — we encourage producers to pursue well-designed breed trials, conduct ISO-compliant life cycle assessments, and publish their findings. The nature-related risks and benefits of higher welfare production also deserve more study. Additionally, the role of higher welfare breeds' lower mortality in reducing upstream and downstream waste of land and water resources merits further study and quantification.

As the year 2030 approaches, the broiler industry faces several possible futures. In one scenario, cumulative land, water, and greenhouse gas impacts increase as they did in the previous decade, alongside global consumption, which is projected to increase 15% between 2022-2032.[83] This scenario is untenable for most stakeholders because it does not achieve decarbonization in line with science-based pathways, and it creates climate-related risks for stakeholders across the supply chain. Perhaps in another scenario, decarbonization is pursued at the expense of welfare, and broilers are "optimized" further for faster weight gain and feed efficiency, or antibiotic use increases. This scenario is also untenable from an ethical standpoint, and it is likely to have diminishing returns from an operational and environmental perspective. Thus, a new paradigm is needed – one in which decarbonization, nature-positive impacts, and animal welfare are pursued in tandem. The interventions described in this report attempt to clarify how this new paradigm might be achieved.

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