
The impact of the Better Chicken Commitment and the use of slower-growing breeds on the welfare of broiler chickens at the farm level: findings and considerations

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Summary

In a series of studies collated in this book we assessed the impact of the adoption of the Better Chicken Commitment (BCC) and the use of slower-growing breeds on the welfare of broiler chickens. To this end, we used an analytical approach (the [Cumulative Pain Framework](#)) that translates evidence on the duration and intensity of the pain associated with these challenges into time spent in four categories of pain intensity (Annoying, Hurtful, Disabling, Excruciating). Each intensity category is defined by specific criteria relating to the disruptive character of the pain experience: from a minimally disrupting (Annoying) to a tormenting state (Excruciating). Through its effects on the welfare challenges investigated (lameness, thermal stress, cardiopulmonary challenges, behavioral deprivation and chronic hunger in broiler breeders), a transition to slower-growing breeds growing at a rate of approximately 45-46g/day, raised under lower stocking densities and slaughtered at 8 weeks is estimated to prevent an average of 25 seconds of Excruciating pain (78% reduction), 33 hours of Disabling pain (66% reduction) and 79 hours of Hurtful pain (24% reduction) for every broiler chicken raised in the reformed scenario instead of conventionally. Estimates are extremely conservative and represent the minimum time in pain expected to be averted at the farm level with the adoption of slower-growing breeds and welfare certification standards such as the BCC. A net positive effect on welfare is also expected for slower-growing breeds growing at rates different than those assumed in this investigation — because most welfare offenses are strongly associated with fast growth, our findings indicate that, in general, the slower the growth rate, the higher the expected welfare impact, despite differences in lifespan. Lameness is responsible for the longest share of a broiler's life in Hurtful and Disabling pain. Although less prevalent, fatal cases of ascites are, in turn, associated with extreme suffering in affected birds. Chronic hunger in broiler breeders is, however, the greatest source of physical pain that any individual chicken (broiler, breeder or egg laying hen) will endure over their life. The burden of Disabling pain resulting from chronic hunger in female breeders is also greater than the burden of pain experienced by the average egg laying hen housed in conventional (battery) cages due to fractures, behavioral deprivation, injurious pecking and egg peritonitis combined. Although beneficial, the adoption of better management practices is limited if the negative welfare effects inherently associated with the genetics for fast growth are not addressed.

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I. Background

In this book we used the [Cumulative Pain Framework](#) [1] to estimate the welfare of commercial broiler chickens in different production scenarios. The framework translates evidence on the duration and intensity of the pain associated with each of multiple welfare challenges typically experienced by a population into time spent in four categories of pain intensity: Annoying, Hurtful, Disabling and Excruciating (Box 1). Pain is operationally defined as ‘any felt negative affective state’, thus encompassing negative affective experiences of both somatic origin (physical pain) and more related to the primary emotional systems (psychological pain). By considering the prevalence of each welfare challenge in the population, estimated times in pain are also determined for the average population member (here, both broiler chickens and broiler breeding females, weighted by their corresponding population sizes). The method is transparent, brings important knowledge gaps into light and incorporates uncertainty about all parameters into the final estimates. Importantly, since the method is based on a universal metric at the heart of how sentient organisms experience life (time), it enables comparing and combining the impact of experiences of very different nature. When this is done, new insights emerge into the conditions and risk factors with the largest impact on well-being.

Commercial broiler production represents some of the most serious animal welfare issues in the livestock industry [2]. Over the last years, campaigns to improve the way broiler chickens are produced, including the use of slower-growing broiler strains, have been gathering pace in many countries. Currently, one of the standards driving the food industry towards higher welfare practices is the [Better Chicken Commitment](#) (BCC), a set of recommendations that can be summarized in five principles: (i) transitioning to **higher welfare breeds** (Hubbard JA757, 787, 957, or 987, Rambler Ranger, Ranger Classic, and Ranger Gold, or others that meet the criteria of the RSPCA Broiler Breed Welfare Assessment Protocol), (2) **reducing stocking density** (maximum of 30 Kg/m²) and prohibiting cages, (3) **provisioning of enriched environments** (light intensity of at least 50 lux, perches and pecking substrates), (4) **improving stunning and slaughter** systems (replacing live-shackling by controlled-atmosphere processing systems that induce an irreversible stun) and (5) demonstrating compliance with the standards via **third-party auditing**.

We therefore used the Cumulative Pain Framework to investigate how adoption of the BCC and similar welfare certification programs is likely to affect the welfare of broilers. Specifically, we examine concerns that the use of slower-growing breeds may increase suffering by extending the life of chickens for the production of the same amount of meat. We analyzed the following scenarios, for which data on broiler welfare was available. First, a **conventional scenario represented by the use of fast-growing breeds** (e.g., Aviagen Ross 308, 708, Cobb 500). Although the performance objectives of these breeds can reach as much as 70 g/day, with birds weighing 2.5 Kg in 35 days [3], average slaughter weight of broilers in the EU and the US is, respectively, 2.5 Kg and 2.9 Kg, reached at 42 and 47 days. This corresponds to an average daily gain (ADG) of 60 and 62 g/day, respectively. We used these values as a benchmark for typical growth rates in fast-growing strains, assuming an ADG of 61 g/day, corresponding to a slaughter weight of 2.5 Kg at 42 days. For the **reformed scenario, represented by the use of a slower-growing strain**, we assumed an average ADG of 45-46 g/day, hence that the same slaughter weight would be reached in approximately 56 days. This is a growth rate consistent with typical figures achieved by various of the breeds approved under the BCC (e.g. JA 987, 787, Ranger Gold), also referred to as medium- or intermediate-growing broilers. This growth

rate also falls within the acceptability of other welfare certification schemes, such as the 'Beter Leven' program in the Netherlands and the 'Deutsche Tierschutzbund' in Germany, which determine a growth rate of up to 45 g/day, and a minimum lifespan of 56 days. Importantly, data on the incidence of important welfare challenges in slower-growing breeds (e.g. proportion of birds with different degrees of lameness) is available predominantly for birds growing at approximately this rate (e.g., [4,5]).

In this Chapter we summarize our main findings and considerations on the impact of these interventions at the farm level. If the reader wants to change any of the assumptions regarding the prevalence, duration and intensity of the pain associated with any of the welfare challenges analyzed, an interactive web application can be used for this purpose, available at <https://pain-track.org/broilers>. In the application, changes in any of the parameters automatically update estimates of the times in pain described here. The welfare impacts of alternative stunning systems are addressed in Chapter 8.

Before describing our findings, we briefly address the trade-off between time of life and quality of life in broiler chickens from a theoretical perspective, discussing important parameters affected by a transition to slower-growing breeds, and their expected impact on welfare.

Box 1 Definition of Pain Intensity Categories

Annoying: experiences of pain perceived as aversive, but not intense enough to disrupt the animal's routine in a way that alters adaptive functioning or affects the behaviors that animals are motivated to perform. Similarly, Annoying pain should not deter individuals from enjoying pleasant experiences with no short-term function (e.g., play) and positive social interactions. Sufferers can ignore this sensation most of the time. Performance of cognitive tasks demanding attention are either not affected or only mildly affected. Physiological departures from expected baseline values are not expected to be present. Vocalizations and other overt expressions of pain should not be observed.

Hurtful: experiences in this category disrupt the ability of individuals to function optimally. Different from Annoying pain, the ability to draw attention away from the sensation of pain is reduced: awareness of pain is likely to be present most of the time, interspersed by brief periods during which pain can be ignored depending on the level of distraction provided by other activities. Individuals can still conduct routine activities that are important in the short-term (e.g. eating, foraging) and perform cognitively demanding tasks, but an impairment in their ability or motivation to do so is likely to be observed. Although animals may still engage in behaviors they are strongly motivated to perform (i.e., exploratory, comfort, sexual, and maintenance behaviors), their frequency or duration is likely to be reduced. Engagement in positive activities with no immediate benefits (e.g., play in piglets, dustbathing in chickens) is not expected. Reduced alertness and inattention to ongoing stimuli may be present. The effect of (effective) drugs (e.g., analgesics if pain is physical, psychotropic drugs in the case of psychological pain) in the alleviation of symptoms is expected.

Disabling: pain at this level takes priority over most bids for behavioral execution, and prevents all forms of enjoyment or positive welfare. Pain is continuously distressing. Individuals affected by harms in this category often change their activity levels drastically (the degree of disruption in the ability of an organism to function optimally should not be confused with the overt expression of pain behaviors, which is less likely in prey species). Inattention and unresponsiveness to milder forms of pain or other ongoing stimuli and surroundings is likely to be observed. Relief often requires higher drug dosages or more powerful drugs. The term Disabling refers to the disability caused by 'pain', not to any structural disability.

Excruciating: all conditions and events associated with extreme levels of pain that are not normally tolerated even if only for a few seconds. In humans, it would mark the threshold of pain under which many people choose to take their life rather than endure the pain. This is the case, for example, of scalding and severe burning events. Behavioral patterns associated with experiences in this category may include loud screaming, involuntary shaking, extreme muscle tension or extreme restlessness. Another criterion is the manifestation of behaviors that individuals would strongly refrain from displaying under normal circumstances, as they threaten body integrity (e.g. running into hazardous areas or exposing oneself to sources of danger, such as predators, as a result of pain or of attempts to alleviate it). The attribution of conditions to this level must therefore be done cautiously. Concealment of pain is not possible.

II. The trade-off between time of life and quality of life in broilers

Since broiler chickens are exposed to multiple welfare challenges during the production cycle, concerns over the adoption of slower-growing breeds are based on the possibility that their longer time of life would translate into a longer time of exposure to conditions causing pain and suffering (in other words, given their painful existence, the sooner it ended, the better).

In general, the welfare challenges that individuals will encounter can either be acute (short-lived) or chronic, accompanying affected individuals until the end of their lives. Unless acute harms leave individuals with sequelae², it is mostly chronic conditions that could affect slower-growing individuals for a longer time, given their longer lifespan.

However, the dynamics underlying the clinical evolution of pathologies over time in breeds with different growth rates makes the problem more nuanced. **The extent to which cumulative pain (of any intensity) endured by slower-growing broilers will differ from that endured by fast-growing birds will depend on at least two parameters: (1) how long each harm is experienced and (2) the proportion of individuals experiencing the harm. Both parameters depend crucially on how quickly a condition emerges and progresses over the production cycle: if a chronic condition has an earlier onset, it will be endured for a longer time. In general, individuals with more risk factors for a condition are also more likely to experience it earlier.** For example, in humans, risk factors such as obesity are associated with an earlier onset of osteoarthritis and metabolic disease [6]. In broilers, lameness appears substantially later in broiler chicks hatched in experimental facilities than in chicks transported from commercial hatcheries, hence exposed to risk factors such as poor hatchery sanitation and shipping stress [7].

This is an important factor to consider, since the cumulative time in pain due to each and every harm experienced by individuals depends on the duration of the pain caused by the harm, not on

² An aftereffect of a disease or experience.

the duration of the life of the individual (although the latter limits the former). Since fast-growth rates and heavy weight in early life are major risk factors for most welfare challenges endured by broiler chickens [2], **these challenges are likely to emerge later in the life of slower-growing birds, to the point that the time they are endured could be the same, or even shorter, in longer-lived slower-growers.** Flocks where chronic conditions appear earlier will also tend to develop higher cumulative incidences when compared with flocks in which the onset of the condition is delayed to later ages [7]. In Figure 1, the temporal progression of a hypothetical welfare offense is simulated for illustrative purposes for fast- (Fig.1A) and slower-growing birds (Fig.1B). In Fig.1B, progression is slower and the onset of the condition is therefore delayed. As a consequence, its prevalence is lower, as well as the ‘cumulative time in pain’ endured by this population (represented by the blue area under the curves).

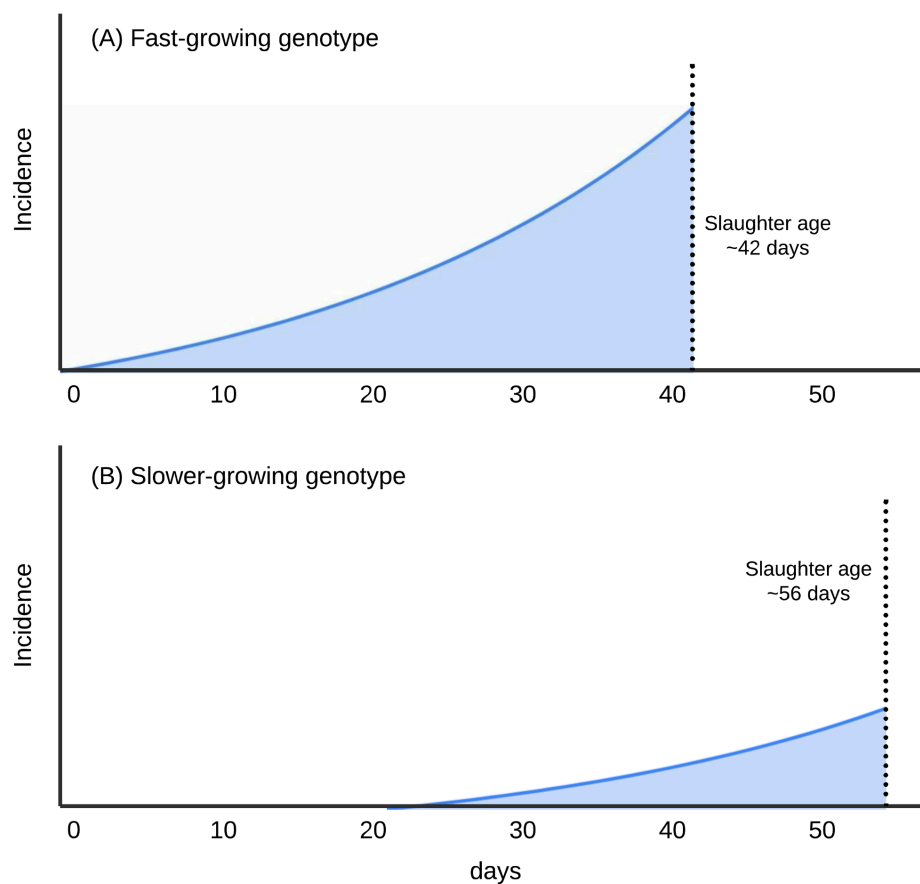


Figure 1. Cumulative incidence of a hypothetical disease over time in two scenarios: (A) birds with an average daily weight gain (ADG) of 61g/day, slaughtered at 42 days, and (B) birds with an ADG of 45-46 g/day, slaughtered at 56 days. Since fast-growth is a major risk factor for most welfare challenges endured by broilers, the emergence of these challenges is typically delayed in the life of slower-growing birds. The blue area represents the cumulative time in pain experienced by the average broiler in the two scenarios.

Still, even in the conservative case where the onset of a harm was the same in fast- and slower-growing birds (hence experienced for a longer time in the latter group), the ‘cumulative time in pain’ experienced by the population can still be shorter in slower-growing breeds depending on the extent to which the prevalence of the harm (height of curves in Figure 1) is lower in these birds. Say, for example, that a hypothetical harm has onset at 2 weeks of age and is experienced until the end of life. In this case, it would be experienced for 6 weeks in slower-growing birds and for 4 weeks in fast-growers. If this harm affected 30% of fast-growing broilers, and in slower-growing breeds has its prevalence reduced to 15%, then the time in pain experienced by the average broiler would still be shorter for slower-growers (6 weeks $\times$ 15% = 0.9 weeks) than for fast-growers (4 weeks $\times$ 30% = 1.2 weeks). In other words, some slower-growing individuals may experience the harm for a longer time than what is typical for a fast-grower, but a much lower number of individuals will experience it, so overall a shorter time in pain is experienced by the slower-growing broiler population.

Finally, the adoption of slower-growing breeds may also affect the presence and severity with which some welfare challenges are experienced. For example, if **disease progression rates are slowed-down, more severe disease stages (those leading to more intense pain) may never be reached.** Similarly, **some conditions (e.g. infectious diseases, cardiopulmonary conditions or feed restriction in parent lines) may not be present in slower-growing birds.**

In this project, we investigated the onset, duration, severity, and prevalence of key welfare challenges affecting fast- and slower-growing broilers (and their parents). In many cases, information on the onset and typical patterns of progression of the welfare offenses was scarce. In such cases, **we preferred to err on the side of caution, and assumed similar disease progression rates in both fast- and slower-growing birds.**

In the next section, we discuss the absolute time in pain endured by individuals affected by each challenge investigated, to then explore their compound effect in the different production scenarios. For a thorough justification of the times in pain shown in the next section, the reader should consult the specific chapters of this book addressing the condition of interest. In these chapters, all parameter values used for the analysis (estimates of duration, intensity, prevalence) are justified (again, the extent to which the estimates are sensitive to our choices and assumptions can be tested at <https://pain-track.org/broilers>).

III. Time in pain endured by individuals affected by each challenge

Figures 2 and 3 show the estimated time that broilers and female breeders spend in Annoying and Hurtful pain (Fig.2), and Disabling and Excruciating pain (Fig.3), as a result of each of the welfare challenges investigated. In the case of lameness-causing conditions, time in pain is disaggregated for the different gait scores (GS1-GS5), as determined using the Bristol Gait Score System (BGSS). This disaggregation is necessary since the results describe the time in pain endured by each ‘individual’ affected, and individuals with different gait scores experience different patterns of pain intensity and duration (Chapter 2). In discussing the results, our focus is on experiences with at least a Hurtful intensity. Annoying pain is considered to be less relevant since, despite its aversive nature, it is a sensation that can be ignored most of the time and does not prevent individuals from enjoying positive welfare states (Box 1).

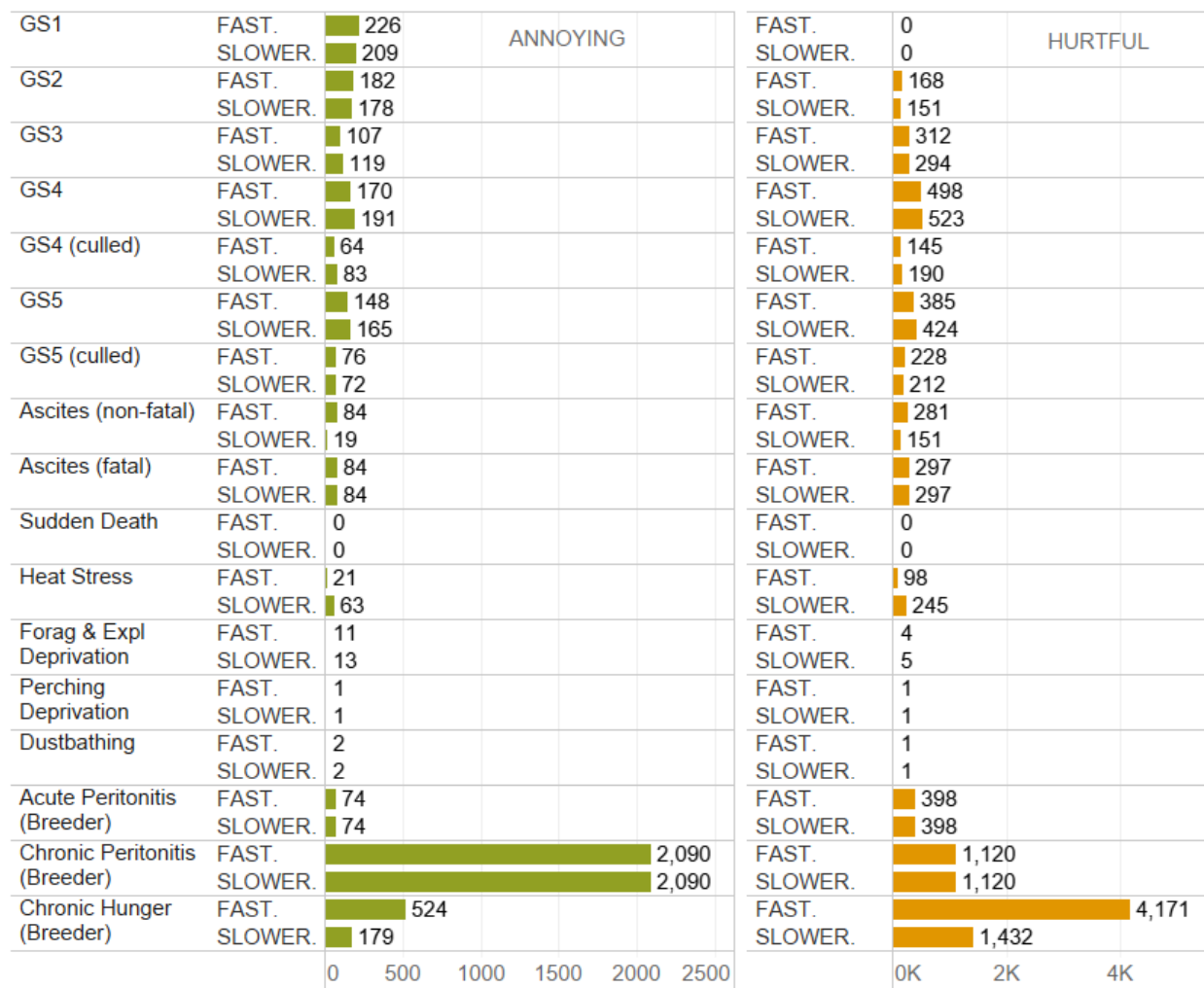


Figure 2. Expected hours in Annoying (green) and Hurtful (orange) pain endured by fast-(F) and slower-growing (S) individuals (broilers and broiler breeders) affected by each of the welfare offenses analysed. GS1-GS5: time in pain endured by lame individuals in each gait score (Bristol Gate Score System). Time scales are different for each category of intensity for greater clarity. Only hours awake are considered. An interactive version of the figure is available at <https://welfarefootprint.org/broilers>.

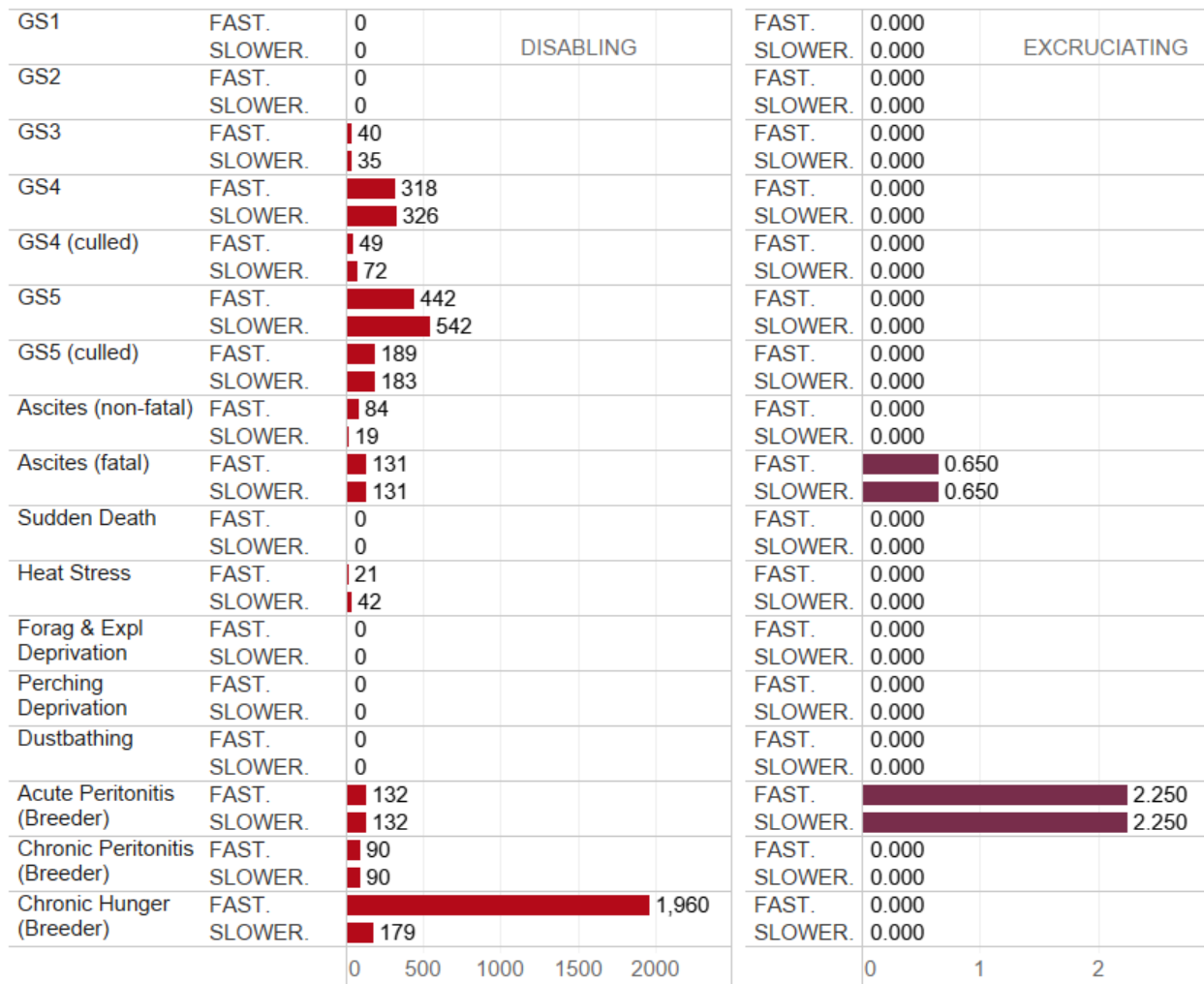


Figure 3. Expected hours in Disabling (red) and Excruciating (purple) pain endured by fast- (F) and slower-growing (S) individuals (broilers and broiler breeders) affected by each welfare offense. Time scales are different for each intensity category for clarity. GS1-GS5: time in pain endured by lame individuals in each gait score (BGSS). Only hours awake are considered. An interactive version of the figure is available at <https://welfarefootprint.org/broilers>.

For broiler (meat) chickens, severe lameness (GS4 and GS5) is responsible for the longest time in Hurtful and Disabling pain, unless birds in these scores are culled soon after (1-5 days) having their walking ability impaired (Chapter 2). Chronic hunger in broiler breeders from fast-growing strains is, however, the greatest source of physical pain that any chicken (broiler, breeder or egg laying hen) will endure over her life. Overall, each conventional female breeder is expected to experience an average of approximately 2,000 [1,830-2,060] hours of Disabling pain and 4,170 [3,830-4,500] hours in Hurtful pain as a result of chronic hunger. These times are substantially longer than the time in pain endured by the average meat broiler as a result of all the ailments analyzed in this book combined (Figure 5).

Broiler breeder females are laying birds with a life expectancy similar to egg-laying hens (60-70 weeks). Yet, **the time in pain breeding females endure due to chronic hunger (1,960 hours of Disabling pain and 4,171 hours of Hurtful pain) is also substantially higher than that experienced by**

egg-laying hens as a result of any of the challenges they face over their life. For example, our previous research has indicated that keel fractures are the greatest source of physical pain that laying hens endure [8]. In general, fractured layers are expected to spend approximately 160 hours in Disabling pain and 2,250 hours in Hurtful pain over their lives as a result of keel fractures [8]. Chronic hunger in breeders thus imposes a substantially greater burden of pain - particularly of the more severe (Disabling) type. This is expected, since broiler breeders are feed deprived since rearing, whereas the onset of keel fractures in laying hens occurs later in life, during production. Additionally, the pain from a fracture has its highest intensity restricted to the period following bone and tissue rupture, then subsiding gradually [8]. Conversely, there is strong evidence to suggest that broiler breeders do not habituate to the sensation of hunger, and that satiety is not achieved even immediately after eating (Chapter 6). **The burden of Disabling pain resulting from chronic hunger in breeders is also greater than the estimated burden of pain for the average egg-laying hen housed in conventional (battery) cages,** estimated at approximately 430 hours of Disabling pain as a result of injurious pecking, keel fractures, peritonitis and different types of behavioral deprivation [9].

Although substantial, the estimated time in pain as a consequence of feed restriction (which could be averted with the use of slower-growing breeder birds) is very conservative. In addition to chronic hunger, feed restriction is also linked with various other negative effects (Chapter 6), including thirst, aggression and higher levels of feather pecking and skin lesions [65]. A higher incidence of foot pad lesions may also be present due to over-drinking in hungry breeders. Moreover, elevated baseline levels of plasma corticosterone have been widely reported in feed-restricted breeders [18,23,66], along with restlessness and a reduced resting time [18,23]. All these factors have been linked to impaired immunity [68–70]. Higher stress levels in female breeders due to hunger can also have long-term consequences for the welfare of their offspring (meat chickens) through epigenetic (transgenerational) effects [78,79], extending the adverse effects of feed restriction to billions of meat chickens every year. Accordingly, chickens born from hens exposed to higher levels of feed deprivation have also shown poorer immune responses [79]. Naturally, heightened susceptibility to infectious diseases translates into additional time in pain, as well as a higher likelihood of exposure to septicemia, the main cause of carcass condemnations in broilers and a condition associated with Excruciating levels of pain [16]. **If these secondary consequences of feed deprivation were considered, the estimated time in fast-growing female breeders would be likely even longer than that presented here.**

The negative consequences of chronic hunger in broiler breeders raise an important point. Although still associated with a net positive impact, **the benefits achieved with implementation of the BCC and slower-growing strains can only be fully realized if both males and females from parent lines are also slower-growing. Commitments based on the use of crosses (e.g. Cobb-Sasso, a cross between fast-growing Cobb 500 females and slower-growing Sasso males) would be, consequently, still associated with severe suffering in one of the parent lines.**

Fatal cases of ascites in broilers (one of the main causes of mortality) in breeders are associated with extreme suffering in affected birds. Victims are estimated to endure approximately 131 [80-180] hours of Disabling pain, and nearly 40 minutes [17-60] of Excruciating pain due to the highly stressful nature of the breathlessness produced by the accumulation of fluid and pressure in the abdomen in the hours preceding death. This is consistent with the report by some authors that death from ascites is usually preceded by prolonged agony [10].

Figures 2 and 3 also enable comparison of the estimates for fast-growing birds slaughtered at 42 days and slower-growing birds slaughtered at 56 days. Except for chronic hunger as a result of feed restriction, the estimated time in pain spent by individuals affected by the different conditions examined was similar in fast- and slower-growing broilers. In other words, even though the prevalence of each of the conditions differed substantially between slower- and fast-growing birds, their impact on welfare was estimated to be similar for those individuals actually affected by each offense. In the case of acute conditions, such as fatal cases ascites and SDS in broilers or egg peritonitis in female breeders, time estimates were the same in both groups. This is expected under the **conservative assumption** that, when emerging, disease progression in such cases will be similar in fast- and slower-growing birds, reaching higher levels of severity in approximately the same time. Since data on disease progression depending on genotype is not available for most conditions investigated, we preferred to err on the side of caution and assume that no differences in the clinical evolution of these pathologies would exist between fast and slower-growing genotypes, even though fast-growing birds are affected by major risk factors for these conditions. For ailments of a chronic nature, some estimates were slightly longer in the case of slower-growing birds, particularly in the case of lameness. This result similarly derives from the **conservative assumption** that disease onset is not substantially delayed for individuals growing at slower rates. Should it be (as it might be; section II), the expected time in pain endured by slower-growers affected by lameness could be shorter than that endured by fast-growing birds.

IV. Relative contribution of each challenge to burden of pain

Figure 4 shows the relative contribution of each welfare challenge to the total time spent in each category of pain intensity by the **average broiler** (an estimate that takes into account the prevalence of the challenge in the population; Box 2). Estimates of the absolute time in pain differed across intensity categories and the two scenarios investigated (Fig.5 and 6), but in Figure 4 total times in pain are scaled to 100% to enable a clearer appreciation of the main drivers of pain in each case.

Box 2 Time in Pain endured by the Average Population Member

Although pain inherently concerns individuals, we operationally accept that the collective welfare of the members of a population can also be determined. Measuring cumulative pain at the population level is also necessary to account for the heterogeneity in the exposure of population members to different challenges. For example, while lameness is experienced by a large fraction of broiler chickens (Chapter 2), events such as fatal cases of ascites are only experienced by a few individuals (Chapter 3).

Therefore, measurement efforts must consider the prevalence of each welfare challenge, so that pain is determined for the average member of the population (which may not necessarily correspond to any real organism). At the population level, the time spent at each level of pain intensity as a result of each challenge is determined by multiplying it by its prevalence. For example, if a condition causes 10 hours of Disabling pain and 70% of the population are affected, then the average member of this population could be said to experience 7 hours of Disabling pain due to the condition. Measurements at the population level enable comparing the impact of different practices and conditions across demographics, geographies and time.

Estimates in Fig.4 confirm the widely held notion that **lameness (orange bars) is the most serious welfare concern in broiler chickens**. Lameness accounts for most of the time spent in Disabling, Hurtful and Annoying pain, due (i) to the painful nature of inflammation caused by cases of infection, trauma and conditions producing abnormal strain on tendons and muscles in severely lame individuals (Chapter 2) [11] and (ii) to the high prevalence of lameness relative to other welfare offenses. A similar pattern is observed in the case of slower-growing breeds. Although the incidence of lameness is greatly reduced in slower-growing birds (Chapter 2), lameness is still responsible for most of the time in pain they endure given the higher prevalence of leg disorders and other lameness-causing conditions relative to the other offenses investigated.

Still, the impact of chronic hunger in female breeders on the time spent in Disabling pain is nearly on par with that caused by lameness. As discussed, chronic hunger is responsible for 1,960 [1,830-2,060] hours of Disabling pain in fast-growing female breeders. When this time is divided by the number of broiler chickens typically produced by each breeder (120-140), this results in an average of 14-16 hours of “breeder pain” from hunger for every broiler chicken produced³. Still, should all the negative impacts of chronic hunger in breeders be considered (eg, aggression, immunosuppression and the transgenerational effects of stress passed on to all offspring; section III), it is possible that the burden of Disabling pain due to hunger for the average fast-growing broiler would be in fact much larger.

³ The burden of pain associated with broiler production must consider not only the welfare of broiler (meat) chickens, but also the share of pain endured by other individuals (life-fates) involved in the production process (in this case, breeders). Approximately 140 broilers are produced per female breeder that reaches the reproductive age. Thus, the time in pain due to each offense in 1 breeder is divided by 120-140 to determine the time of ‘breeder pain’ per broiler produced.

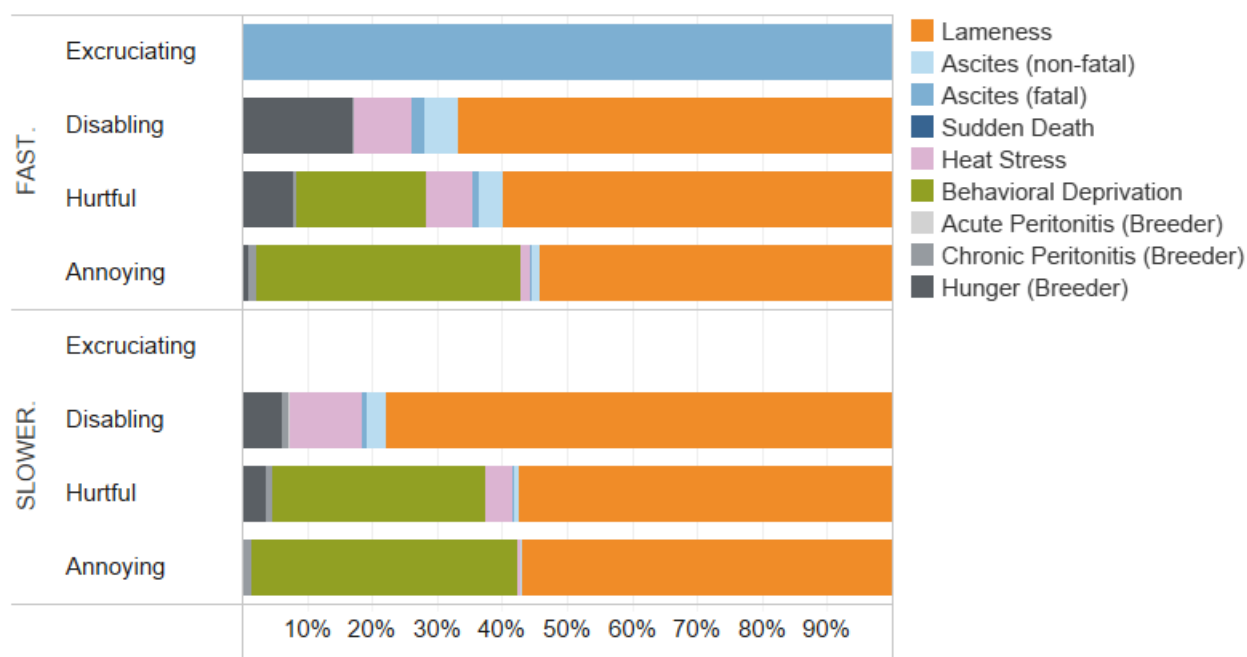


Figure 4. Contribution of each harm **relative** to the total estimated time (scaled to 100%) endured **by the average broiler (i.e. weighted by prevalence)** in the four categories of pain intensity. Here, the absolute size of each colored bar should not be compared across intensities or systems (see <https://welfarefootprint.org/broilers> for a dynamic figure that enables inspecting values).

Figure 4 also shows that the expected time in pain due to heat stress, as estimated based on the typical proportion of birds panting over the production cycle, is longer than that caused by all cardiopulmonary conditions. This is expected, since the cardiopulmonary challenges analyzed (pulmonary hypertension/ascites and SDS) are estimated to affect a much lower proportion of individuals than those affected by heat stress, and in some cases (SDS) their effects are short-lasting (Chapter 3).

The impact of behavioral deprivation (deprivation of the opportunities to forage and explore, or to perch) is restricted to lower levels of intensity given the lack of measurable negative impacts of their deprivation on broiler welfare (e.g. aggression, the performance of abnormal behaviors, physiological indicators of stress) and the observation that the ability to function, in terms of performing important maintenance behaviors such as eating and drinking, is not substantially disrupted (Chapter 5). Here, differences in the time spent in pain between fast- and slower-growing birds are mostly due to differences in (1) their lifespan and (2) the time budget allocated to behavioral opportunities by the two genotypes. Although slower-growing broilers are more active, they still spend most of their day inactive (Chapter 5).

Finally, nearly all of the time in Excruciating pain derives from fatal cases of ascites. A small proportion of this time is attributed to acute cases of peritonitis in breeders, but the effect is diluted when this estimate is divided by the number of broilers (~140) produced by each breeder (i.e. to establish the “breeder pain” from peritonitis for every broiler chicken produced). The observation

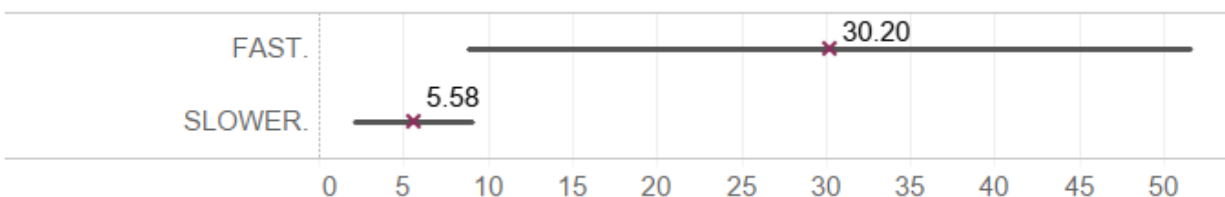
that ascites is responsible for nearly all the burden of Excruciating pain does not mean, however, that other conditions (not measured) cannot produce pain at this level of intensity. Excruciating pain is expected in most cases where infectious conditions progress to severe sepsis accompanied by major organ failure [12].

V. Impact of the adoption of BCC standards and slower-growing strains

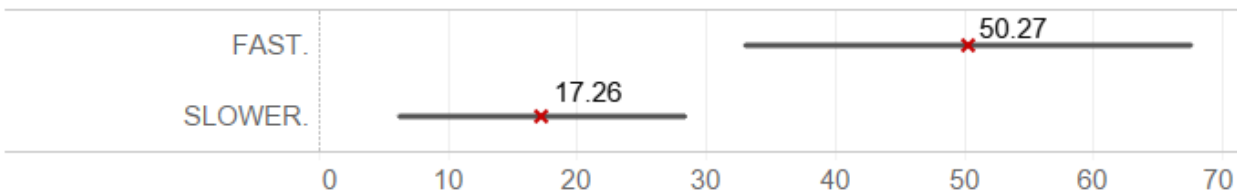
Figure 5 shows the estimated number of hours endured in the four categories of pain intensity by the average broiler chicken in the two scenarios as a result of all welfare challenges combined, along with the estimated time in pain averted by the adoption of breeds growing at approximately 45-46g/day under the BCC. In Figure 6 the same data is disaggregated by challenge.

Through its effects on the welfare challenges investigated here, **the adoption of slower-growing birds reaching a slaughter weight of approximately 2.5 Kg at 56 days (reformed scenario) is expected to prevent at least 33 [13 to 53] hours of Disabling pain, 79 [-99 to 260] hours of Hurtful and 25 [5 to 45] seconds of Excruciating pain for every broiler chicken raised in the reformed scenario instead of conventionally. These figures correspond to approximately 66%, 24% and 78% reduction, respectively, in the time experienced in Disabling, Hurtful and Excruciating pain for each broiler chicken affected by the reform.**

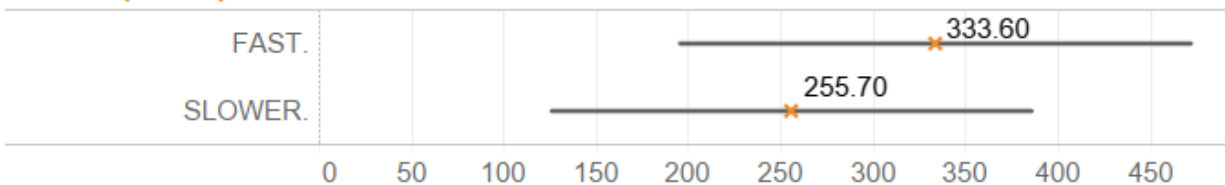
Excruciating (SECONDS)



Disabling (hours)



Hurtful (hours)



Annoying (hours)

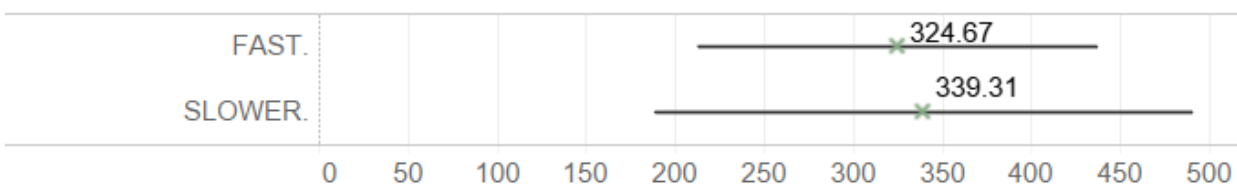


Figure 5. Expected time in pain endured by the average broiler in each category of pain intensity in fast- (F) and slower-growing (S) breeds. Time scales are different for each category of intensity for greater clarity. Only hours awake are considered. An interactive version of the figure is available at <https://welfarefootprint.org/broilers>.

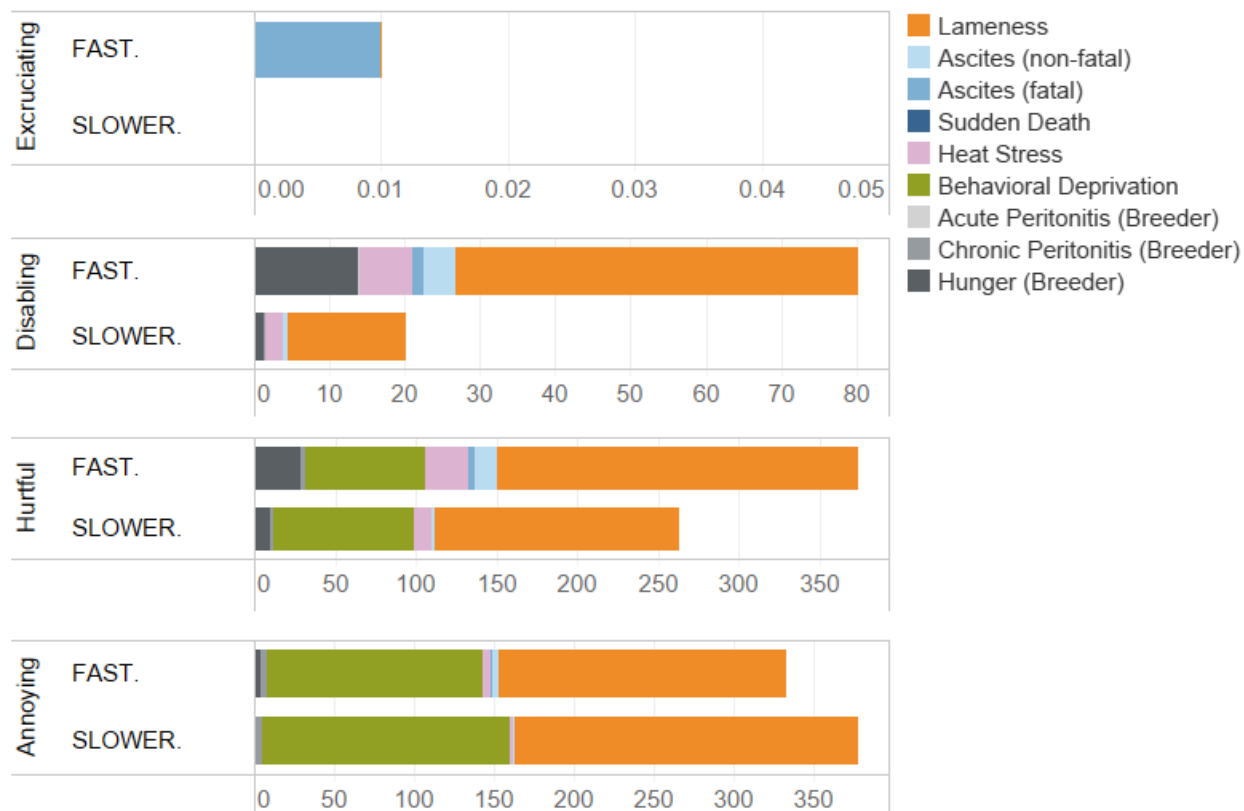


Figure 6. Expected time in pain (hours) endured by the average broiler in each scenario and intensity category, disaggregated by harm. Time scales are specific for each intensity category for greater clarity. Only hours awake are considered. An interactive version of the figure is available at <https://welfarefootprint.org/broilers>.

V.1 Why our estimates are conservative

The present estimates are conservative, representing the ‘minimum’ time in pain expected to be averted, at the farm level, with the adoption of slower-growing breeds under certification standards such as the BCC (Table 1). For example, in the case of lameness-causing conditions, the main welfare concern for broilers, prevalence estimates for conventional strains were mostly derived from northern European countries, which possibly have better welfare standards than major chicken producing economies such as the United States, Brazil and China. For example, data from 11 randomly chosen farms in Brazil [13] point to a substantially higher proportion of lame birds, with an average proportion of birds unable to walk of 14%, compared to only 3-5% in the UK, Netherlands and Italy (Chapter 2).

Additionally, the estimates do not emerge from an exhaustive analysis of every possible welfare challenge affecting broilers, such as infectious and inflammatory conditions (e.g. pericarditis, cellulitis, dermatitis, hepatitis), contact dermatitis (e.g., footpad dermatitis, hock burns) and muscle abnormalities potentially associated with poor welfare (e.g., white stripping, wooden breast). Evidence suggests that the incidence of all these offenses is substantially higher in fast-growing birds [4,5,14]. For example, about 20 to 70% of commercial fast-growing broilers can be affected by footpad dermatitis (FPD) [15–17]. Because FPD is one of the conditions that can lead to lameness (Chapter 2),

and our analyses take into account the time spent in pain due to lameness, we have not analyzed FPD separately to avoid duplicating the time in pain associated with this condition. Still, to the extent that the pain from FPD and lameness are not completely overlapping, considering FPD would increase the time in pain spent by fast-growing strains (prevalence of FPD in these birds is substantially higher than in slower-growing strains, particularly if produced under lower stocking densities [4,5]).

Table 1. Welfare harms excluded from analysis, which if considered would increase further the estimated benefits of the transition to slower growing breeds.

Source*	Life Fate	Life Phase	Welfare Harms
1	Male Breeders	All Phases	Chronic Hunger and secondary effects of hunger
2	Female Breeders	All Phases	Secondary effects of chronic hunger (thirst, aggression, epigenetic effects on offspring)
3	All	Transport to slaughter	All harms at this phase (heat stress, fractures, thirst, hunger)
4	Broilers	Day one to slaughter day	Infectious diseases
5	Broilers	Day one to slaughter day	Muscle abnormalities
6	Broilers	Day one to slaughter day	Other Inflammatory conditions (e.g. pericarditis, cellulitis, dermatitis, hepatitis)
7	Broilers	Day one to slaughter day	Contact dermatitis
8	Broilers	Day one to slaughter day	Discomfort from poor air quality
9	Broilers	Day one to slaughter day	Disrupted resting
10	Broilers	Day one to slaughter day	Ectoparasites (mites)

*(1) Males in the parent stock of fast-growing breeds are also exposed to restricted feeding schedules and experience chronic hunger (though the effect is small since the proportion of male breeders to broilers is very low); (2) In addition to hunger, fast-growing female breeders are likely to experience various other negative effects of feeding restriction, including thirst, aggression and higher levels of feather pecking and skin lesions; (3) Fast-growing strains are less tolerant to heat stress, hunger, and have worse gait scores, making the journey to the slaughterhouse more strenuous; (4) Faster growth is associated with poorer immune function, impaired maturation of the immune system, lower magnitudes of immune responses, and impaired production of antibodies. Accordingly, heavy and faster growing lines have lower resistance to infectious diseases and a higher likelihood of mortality from infection; (5, 6,7) incidence of all these offenses is substantially higher in fast-growing birds; (8) Air quality is expected to be worse for birds with higher metabolic rates and kept under higher stocking densities, given the poorer litter quality from higher waste volume per area; (9) Higher stocking densities translate into higher likelihood of disrupted resting in fast-growing birds; (10) Fast-growing broilers are more susceptible to stress, and have more vulnerable immune systems, which make them less capable of warding off parasites. Higher stocking densities are also a risk factor.

Similarly, faster growth is associated with poorer immune function, as energy that would otherwise be used for defense is diverted to growth and reproduction [18]. By limiting the energy available for other physiological demands, selection for faster growth has impaired the maturation of the immune system, the magnitude of the immune response [19–22], and the production of antibodies [23,24]. Accordingly, heavy and faster growing poultry lines have shown lower resistance to multiple

infectious diseases [19,22,23,25–29] and a higher likelihood of mortality from infection compared to slower-growing strains [20,30,31]. This heightened susceptibility of conventional strains to infectious diseases should translate into additional time in pain, as well as a higher likelihood of exposure to septicemia, one of the main causes of carcass condemnations in broilers and a condition associated with Excruciating levels of pain [12]. Poor disease resistance is likely to become an increasingly greater problem, and source of pain, in fast-growing broilers following the ban on the use of in-feed antibiotics in poultry farms.

Air quality is also expected to be worse in the conventional scenario, given higher stocking densities and poorer litter quality (e.g. from higher waste volume per area and higher levels of immobility). Yet the effect of poor air quality on welfare was not considered in the estimates. Higher stocking densities should also translate into higher likelihood of disrupted resting [32] in fast-growing birds, which in turn is associated with poorer immune function [33,34].

Likewise, we limited the analysis of the effects of feed restriction in broiler breeders to the impact of chronic hunger alone, but as discussed previously (section III) feed restriction is associated with a cascade of multiple additional negative welfare effects. Should the time in pain due to these additional challenges be factored in the quantitative analysis, it would further increase the burden of pain in fast-growing genotypes relative to slower-growers.

Finally, although our focus is on the measurement of affective states of a negative valence, the reduction of the time in pain observed in slower-growing broilers should also enable birds to enjoy experiences of positive welfare more frequently (or for a longer time). Indeed, where investigated, slower-growing birds have been shown to display a higher frequency of positive behaviors (e.g. dust-bathing, exploration, comfort behaviors) than fast-growing birds raised in similar conditions (e.g., [5,35], Chapter 5). To the extent that positive experiences can compensate for negative ones, this would further reduce the cumulative burden of negative experiences in slower-growers relative to fast-growers. Most obviously, engagement in behaviors such as dust-bathing and exploration is a strong indicator of positive welfare (these behaviors are not expected in animals affected by pain, distress, fear or poor health). Therefore, observations of their higher frequency in slower-growing genotypes coincide with our estimates of better welfare (shorter times in pain) in these birds.

V.2 Effect of Reforms on the Number of Individuals Produced

Adoption of slower-growing birds could affect the number of individuals needed to produce the same amount of meat in different ways. In this section we discuss whether and how this may happen.

Evidence suggests that mortality rates are substantially higher in fast-growing breeds, from approximately 25% up to 270% [5,36,37]. Naturally, a higher mortality should translate into the need of a higher number of individuals to produce the same amount of meat. Considering typical pre-slaughter mortality rates in conventional broilers (approximately 5% [38]), transition to slower-growing strains should reduce the number of individuals raised and slaughtered by approximately 1% to 4%. Improvement of immune function resulting from the use of healthier breeds and lower stocking densities should also translate into a lower likelihood of infectious disease

outbreaks, associated with the mass culling of millions of birds every year (and not considered in statistics of 'normal' mortality).

Second, broilers breeds with faster growth rate and higher breast yield are more likely to be affected by muscle abnormalities [4,14,39], such as white stripping, wooden breast and spaghetti meat, which often result in downgrading and withdrawal from the food chain [39,40]. Losses as a result of these myopathies have been estimated at around 1% of production [41,42], though more recent studies claim that this figure is an underestimate, with actual figures being far higher [41]. Meat loss from breasts accepted as suitable for human consumption will also be present on the consumer side, owing to the need of trimming, decreased yield (increased drip and cook losses) and rejection due to undesirable sensory properties [39]. For example, significantly higher cooking loss was observed in meat affected by myopathies (20.6%) compared to unaffected meat (17.0%) [43]. As with mortality, this translates into the need of a higher number of individuals (tentatively estimated at 1-3% more, assuming the more conservative estimates) for producing the same amount of marketable and acceptable meat on the consumer plate. These additional losses from mortality, disposal and rejection of meat from fast-growing birds (conservatively estimated at 2-7%) are likely to counterbalance potential differences in meat yield between fast- and slower-growing strains, estimated to be about 1% lower in slower-growing birds (71% eviscerated weight) compared to standard birds (72%) [37].

Additionally, adoption of higher welfare breeds may also reduce the number of broiler chickens produced by reducing demand for chicken meat due to its higher cost of production [37]. In one study, production costs were estimated to increase by about 14% and retail chicken prices by 1.17%, which was estimated to reduce the amount of chicken sold by 0.91% [44]. In two industry reports, the production of slower-growing breeds was estimated to cost 16% and 23% more relative to prevailing production standards in the UK and Netherlands, respectively [37], and up to 49% more in the United States [45]. In such cases, the reduction in the demand for chicken meat could be higher.

When these factors are considered together, adoption of slower-growing birds could lead to a reduction in the number of individuals produced if birds are slaughtered at the same weight. However, in a recent analysis, Lusk and collaborators [44] estimate that slaughtering slower-growing chickens at a slightly (~10%) earlier age would optimize net returns. Assuming typical growth rates for the breeds analyzed, this would translate into approximately 10% less weight at slaughter, hence potentially into the need for raising and slaughtering more chickens. Although the model does not consider the production, processing and packaging costs of birds with heterogeneous sizes (e.g. need to change processing and packaging machinery), or consumer preference for heavier birds [46,47], it is important to consider the possible welfare implications should it be realized. Slaughtering slower-growing chickens at a slightly lower weight may translate into a higher number of birds produced. This increase would be partially offset by the lower number of individuals lost to mortality, disposal and rejection, as well as owing to the higher product costs (tentatively estimated at 3-9%, as reviewed before).

We find it unlikely though that the additional time in pain associated with a small increase in the number of individuals would outweigh the estimated benefits achieved with implementation of the BCC and similar standards. First, this increase is substantially lower than the 67%, 26% and 78% reduction, respectively, in the time experienced in Disabling, Hurtful and Excruciating pain for each broiler chicken affected by the BCC reform at the farm level. Second, welfare deteriorates with age, being disproportionately worse as birds approach the slaughter age. Not only are existing conditions aggravated as birds age and gain weight, but also many welfare offenses have their onset later in life.

Because the last days of life are the worst from a welfare perspective, a 10% shorter lifespan age should spare slower-growing broilers from the most severe welfare outcomes experienced at the farm level, reducing the estimated times in pain substantially. Also, although the stunning and slaughter process are hotspots of suffering, concentrating the exposure of birds to acute pain in a short time period, [estimated times in pain at the slaughter plant](#), of all intensities, are substantially lower (in the order of seconds to slightly over a minute, depending on intensity) than the times in pain (at the corresponding intensities) at the farm level, even if electrical waterbath systems involving live-shackling are used for stunning (see Chapter 8). So even if more individuals went through the stunning and slaughter experience, the additional time in pain endured, of all intensities, would still be shorter than the time in pain averted with the reform (particularly considering the conservative nature of the estimates).

VI. The potential for welfare improvement solely through management

It is widely acknowledged in the animal welfare literature that the major welfare offenses experienced by modern broilers are associated with genetic selection narrowly focused on rapid growth and high breast yields (reviewed in [2]). Our findings are consistent with this view. As we discuss in this section, **although the adoption of better management practices - including lower stocking density, longer resting times and the provision of enrichment, as proposed in the BCC - is beneficial and desirable for improving broiler welfare, their impact is limited if the negative welfare effects inherently associated with the genetics for fast growth are not addressed.**

For example, in fast-growing breeds, energy is diverted primarily towards muscle deposition, causing development of critical organs - including the heart and lungs - to lag behind (Chapter 3). Cardiorespiratory function is also compromised by the increased demand for oxygen, leading to the emergence of conditions such as ascites and SDS. These challenges are made worse by poor environmental conditions. For example, higher stocking density is commonly associated with poor litter and air quality, increasing respiratory stress [50]. Similarly, shorter resting periods resulting from insufficient hours of darkness increase strain on the cardiovascular system [51,52]. Accordingly, some improvement in the severity and incidence of these conditions can be achieved by reducing stocking density and increasing resting time [53–55]. However, such improvements are limited when compared to those achieved with the use of slower-growing breeds, from which cardiopulmonary risks can be virtually eliminated (Chapter 3).

Similar patterns are observed with other welfare challenges. This is the case of heat stress, another source of poor welfare in poultry. High stocking density increases the likelihood and severity of heat stress as it makes heat dissipation more difficult. Additionally, it also leads to an increased production of feces, which increases litter moisture and nitrogen content, hence greater production of ammonia and heat [56]. Still, fast-growing strains are at a considerably higher risk of heat stress even at lower densities owing to their higher metabolic rate, greater production of body heat and higher feed-induced thermogenesis [57–60] (Chapter 4). Slower-growing birds are, conversely, more capable of withstanding high thermal conditions [61–63]. As discussed in section V.1, immune function is also compromised by rapid growth [18,64], with faster growing poultry lines showing lower resistance to multiple infectious diseases [19,22,23,25–29].

Although beneficial, management interventions, such as a reduction of stocking density, also seem to have a limited effect on the mitigation of lameness. On the one hand, high densities have been

associated with greater severity of leg issues [5,56,65,66] and a higher incidence of leg culls [67–69]. Evidence indicates that the effect of stocking density on lameness is mediated predominantly by housing conditions: by limiting the space available for movement and creating a greater volume of waste per area [67], high stocking densities lead to greater litter moisture and poorer air quality [56,68,70], which are important risk factors for lameness [71,72]. Yet if the enforcement of a lower stocking density is not accompanied by the good levels of husbandry needed to control litter temperature, moisture and ammonia levels its effect on leg health will be possibly limited⁴. Importantly, fast-growth is associated with leg health abnormalities that can hardly be mitigated with better environmental management and lower densities. Because bone development is not as rapid as the rate of muscle deposition [74], disproportionate stress is placed on immature bones and joints [2,75]. Additionally, gait modifications caused by disproportionately heavy breasts further increase the risk of skeletal and muscle disorders [56,74,76,77]. This creates a vicious cycle, in that gait modifications and reduced locomotion further predispose the birds to skeletal and muscle disorders [14,16–18]. Accordingly, we did not find a strong link between lameness and stocking density (Chapter 2). For example, very low stocking densities in Italy (13 Kg/m²) and Brazil (27 Kg/m²) did not prevent a very high prevalence of GS ≥ 3 scores (~31% and 83%, respectively).

A similar pattern is observed in the case of enrichment. For example, in addition to allowing for elevated roosting (potentially reducing fear; Chapter 5), provisioning of perches has been linked to better gait scores [78], reduced time in contact with the litter [79], lower incidences of footpad dermatitis [80], as well as improved thermoregulation [81]. Yet, fast-growing birds in enriched environments do not make use of behavioral opportunities in the same way slower-growing birds do [82,83], using perches much less frequently [4,35]. In general, fast-growing broilers spend more time inactive and sitting on the floor than slower-growing birds (Chapter 5), even when appropriate enrichment is provisioned.

Finally, the negative impact of genetics on welfare is perhaps most obvious in the case of broiler breeders. While typically sharing the genetics for fast-growth and high feed conversion, breeders must be subjected to severe levels of feed restriction to slow down growth and prevent the health and reproductive issues associated with obesity. Such a band-aid solution has had a cascade of multiple adverse effects on welfare, the most prominent being chronic hunger. As discussed, chronic hunger in breeders is the greatest source of physical pain that any chicken will endure over her life. Although several strategies to alleviate the sensation of hunger and its welfare consequences have been studied (e.g., addition of bulky fibers to the diet, use of feeding schedules consisting of larger feed amounts on some days followed by off-feed days [84,85], use of appetite suppressants), their effects on welfare have proved limited and controversial [85–87]. In turn, because slower-growing genotypes can be raised without feed restriction [23,24], hunger is an unlikely challenge for these birds.

Overall, these observations are in line with the conclusion of the European Food Safety Agency and recent experimental trials showing that, although beneficial, **animal husbandry options to prevent the negative side effects of genetic selection for fast growth are limited [5,84,88], and outweighed by the benefits achieved with the use of slower-growing breeds.** They also reinforce the notion that *‘any environmental improvements must be accompanied by a switch to chicken breed strains with better health and behavioral capacities’* [89].

⁴ Ensuring good husbandry is very challenging. For example, it is estimated that ~1.5 to 4.6 billion broiler chickens slaughtered every year in the European Union (21–66% of the EU production) may be kept at high densities without the required additional welfare conditions set by the Council Directive 2007/43/EC [73], which include limits on the concentration of gasses, temperature, humidity and mortality at higher densities.

VII. General Conclusions

Our results strongly support the notion that the adoption of slower-growing broiler strains will improve the net welfare of broiler chickens. They oppose claims that, from a welfare perspective, “*it is difficult to conclude that the use of such breeds offer a significant advantage over faster growing breeds under commercial conditions*” [72]. Despite our deliberate efforts to avoid inflating the welfare benefits of a reformed scenario (section V.1), for every welfare harm investigated, and for all harms combined, our estimates point to a clear reduction of the time in pain at the farm level, particularly of higher intensities, with the adoption of BCC standards and slower-growing breeds in general. A summary of our main findings is available in Box 3.

Box 3 Main Findings

- Our results strongly support the notion that **adoption of BCC standards and slower-growing broiler strains have a net positive effect on the welfare of broiler chickens**. Because most welfare offenses endured by broilers are strongly associated with fast growth, **adoption of slower-growing breeds not only reduces the incidence of these offenses but also delays their onset**. As a consequence, slower-growing birds are expected to experience a shorter, not longer, time in pain before being slaughtered.
- Adoption of the Better Chicken Commitment, with use of a slower-growing breed reaching a slaughter weight of approximately 2.5 Kg at 56 days (ADG=45-46 g/day) is expected to prevent at least 33 [13 to 53] hours of Disabling pain, 79 [-99 to 260] hours of Hurtful and 25 [5 to 45] seconds of Excruciating pain for every bird affected by this intervention (only hours awake are considered). These figures correspond to approximately 66%, 24% and 78% reduction, respectively, in the time experienced in Disabling, Hurtful and Excruciating pain relative to a conventional scenario due to lameness, cardiopulmonary disorders, behavioral deprivation and thermal stress.
- **The estimates are conservative, representing the minimum time in pain expected to be averted with implementation of the BCC and similar standards**. Among other things, they do not consider other welfare challenges with a higher incidence in fast-growing birds (e.g. infectious diseases, inflammatory conditions, contact dermatitis, muscle abnormalities, the negative effects of feed deprivation in conventional breeders other than chronic hunger) and the greater exposure of these birds to environmental stressors such as poorer air quality, litter quality and disrupted resting.
- In general, the slower the growth rate, the shorter the cumulative time in pain experience over a lifetime, despite differences in lifespan. Should breeds with growth rates slower than those assumed in the reformed scenario be used, the time in pain averted with the reform would be longer, despite a longer lifespan. By the same logic, slower-growing breeds growing faster (e.g. 50g/day) should endure a longer time in pain, despite their shorter lifespan. In all cases, reforms promoting a transition to slower-growing breeds should expect a reduction of the cumulative time in pain (net positive change) for all breeds considered under the BCC scheme: **the slower the growth rate, the higher the expected welfare impact**.
- **Adoption of slower-growing birds reaching a similar slaughter weight as conventional breeds is also likely to lead to a reduction in the number of individuals needed to produce the same amount of meat** given reduced losses from mortality, as well as from disposal and rejection of carcasses and meat products (e.g. lower incidence of muscle myopathies) at the production and consumer sides. Demand for chicken meat may also be reduced due to the higher costs of production.
- **Lameness is the most serious welfare concern for the average broiler chicken**.
- The negative **impact of heat stress on the welfare of the average broiler is substantially larger than the impact of cardiopulmonary challenges** (ascites and sudden death syndrome) given their relatively low prevalence.
- **Fatal cases of ascites (one of the main causes of mortality in broilers) are associated with extreme suffering** (nearly 40 minutes in Excruciating pain) in affected birds.

- **Chronic hunger from feed restriction in broiler breeders is the greatest source of physical pain that any individual chicken will endure over her life.** Female breeders from fast-growing strains are estimated to experience at least 2,000 hours of Disabling pain and 4,170 hours in Hurtful pain as a result of hunger. Additional welfare challenges (not considered) emerging from feed restriction include aggression, higher incidence of feather pecking, skin lesions, foot pad lesions, disrupted resting, impaired immunity and long-term consequences for the welfare of offspring (meat chickens) through epigenetic effects. Therefore, although still associated with a net positive impact, **the benefits achieved with implementation of the BCC and slower-growing strains can only be fully realized if both males and females from parent lines are also slower-growing.** Commitments based on the use of crosses (e.g. Cobb-Sasso) would be, consequently, still associated with severe suffering in parent birds.
- Although the adoption of better management practices - including lower stocking density, longer resting times and the provision of enrichment - is beneficial and desirable for improving broiler welfare, **their impact is limited if the negative welfare effects inherently associated with the genetics for fast growth are not addressed.**
- Any implementation of the BCC and similar commitments should **ensure that the use of higher welfare breeds happens concomitantly with the monitoring of their growth rate under ad libitum feeding conditions. Importantly, the incidence of different welfare outcomes should be closely monitored.** The importance of 'demonstrating compliance with the standards via third-party auditing cannot be overstated

VII. 1 Adoption of slower-growing breeds with growth rates different than those assumed

In the present analyses, we compared a baseline scenario represented by the use of conventional breeds growing at approximately 61 g/day and slaughtered at 42 days with a reformed scenario, represented by breeds grown up to 8 weeks with a slightly lower growth rate (ADG=45-46 g/day, the growth rate for which data on the incidence of several welfare challenges was available). **Our findings indicate that, in general, the slower the growth rate, the shorter the cumulative time in pain experience over their lifetime, despite differences in lifespan.**

Should breeds with growth rates slower than those assumed in the reformed scenario be used, we predict that the time in pain averted with the reform would be longer, despite these breeds' longer lifespan (e.g., 9-12 weeks for breeds growing less than 42 g/day). As discussed, the onset of important welfare challenges is expected to be delayed to much later in life in such cases (Fig.1), or they may not emerge at all. For example, the prevalence of gait scores GS2-5 in the slower-growing Rowan Range (ADG=38-42g/day [90]) at 9 weeks of age was shown to be ~27% [91]. This is a much lower figure than our assumption 30-89% (at 8 weeks) used in the present analyses. This is consistent with the notion that **in birds with progressively slower growth rates the biomechanical constraints that compromise walking ability and leg function are increasingly alleviated, delaying disease emergence, to the point that leg disorders may become unlikely to emerge at all in birds that grow very slowly.** The same rationale applies to other welfare problems associated with fast growth.

By the same logic, slower-growing breeds growing faster (e.g. 50g/day) than the rate assumed in our reformed scenario should endure a slightly longer time in pain than that estimated here, despite their shorter time of life. In this case, the impact of the adoption of slower-growing breeds would be lower

than that estimated here, but still positive (i.e., since the expected time in pain endured over their life should be shorter than that experienced by conventional breeds growing at an even faster rate; typically ≥ 60 g/day). In other words, **reforms promoting a transition to slower-growing breeds should expect a reduction of the cumulative time in pain (net positive change) for all breeds considered under the BCC scheme: the slower the growth rate, the higher the expected welfare impact.**

Despite the importance of growth rate in the emergence of multiple welfare outcomes, our results obviously do not apply to cases where growth is slowed down by adjusting either the quality or quantity of feed to delay the time taken to reach slaughter weight. Nor will they apply to the higher welfare breeds currently considered under the BCC and other certification schemes if these breeds are subsequently subject to genetic selection or nutritional management that increases the incidence of the welfare offenses investigated. Ideally, **any implementation of these commitments should ensure that the use of higher welfare breeds happens concomitantly with the monitoring of their growth rate under ad libitum feeding conditions.** Importantly, **the incidence of different welfare outcomes should be closely monitored**, for example by the enforcement of rigorous pass/fail criteria in inspections at the abattoir, by independent welfare auditing at depopulation and the implementation of mechanisms to improve transparency in the production and finishing chains [92]. The importance of ‘demonstrating compliance with these standards via third-party auditing’, as required under the BCC, cannot be overstated.

VII. 2 Comparison of reform impact in broilers and egg laying hens

In comparing the benefits of different welfare reforms for chickens, **the estimated time in Disabling, and Hurtful pain averted per each broiler chicken affected is, respectively, 13% and 4% of that averted for every egg-laying hen housed in an aviary instead of a conventional cage [9] (Table 2).** However, because laying hens are outnumbered by broiler chickens (roughly ten broiler chickens are born in a year for every egg-laying hen on the planet), the impact of welfare reforms for broilers (time in pain averted) is potentially greater than the impact of welfare reforms for egg layers. Time in Excruciating pain is only averted in the broiler reforms. In both cases, however, estimates do not derive from an exhaustive list of every welfare offense experienced by broilers or layers, hence they should be taken with caution as they may vary when other welfare offenses are considered.

Table 2. Estimates of the minimum time in pain averted per bird affected by welfare reforms for broiler chickens (adoption of slower-growing strains growing at 45-46 g/day) and egg-laying hens .

	Minimum Time in Pain Averted per Bird		
Pain Intensity	Adoption of BCC at the farm level: impact per average broiler	Adoption slower-growing breeds: impact per female breeder	Transition from conventional cages to aviaries: impact per egg-laying hen
Excruciating	25 [5 to 45] seconds		
Disabling	33 [13 to 53] hours	1,800 [1,700 to 1,900] hours	275 [180 to 370] hours
Hurtful	79 [-99 to 260] hours	2,700 [2,400 to 3,100] hours	2,313 [1,200 to 3,400] hours

VIII. Research Gaps and Opportunities

Naturally, our estimates are only as good as the data feeding them. Although time is at the heart of how individuals experience life, **the temporal dimension of the welfare outcomes experienced by farm animals has been greatly overlooked in the animal welfare sciences.** Little is known about typical times of onset of the many harms affecting chickens or, importantly, for how long they are endured. Likewise, surveys on the prevalence of different welfare outcomes under commercial conditions for fast- and slower-growing strains are scarce, particularly in regions other than Europe. Importantly, few are the welfare challenges for which there are studies exploring the possible intensity of the negative affective experience they impose, as perceived by the individuals affected. For example, as far as we are aware, no description is available on the clinical evolution of septicemia in chickens and the sensorial and affective consequences for affected animals, even though it is a very painful condition and one of the most frequent causes of carcass condemnation in the poultry industry (a list of research gaps is given in Box 4). In previous chapters, each numerical input used in the Pain-Tracks was justified based on a comprehensive review of knowledge gathered from different disciplines, and assumptions about the intensity and duration of the pain associated with each welfare offense was made explicit. Additionally, we incorporated uncertainty and the expected variability around each parameter's value into the estimates through the use of wide uncertainty intervals, instead of using (unrealistically) precise point estimates. However, because evidence used to fill in the Pain-Track is limited, criticism of the proposed values is very much encouraged to drive targeted progress in this area.

Box 4. Knowledge Gaps and Research Opportunities

- Although time is at the heart of how conscious organisms experience life, the temporal dimension of the welfare outcomes experienced by non-human animals has been greatly overlooked in the animal welfare sciences. **Little attention has been paid to understanding when diseases emerge, how long disease states last, or how quickly they progress. Longitudinal studies following individuals over time are very much needed.**
- Very few studies have examined the progression of lameness in broilers over time. **Longitudinal data are needed to establish patterns of disease onset and progression for birds with different gait scores at the end of production.** This knowledge is critical to establish more accurately the time that broilers affected by lameness spend in pain.
- Similarly, **data is very scarce on the onset and progression of lameness in slower-growing breeds of broilers.** Knowledge is not yet available on the extent to which the onset of lameness changes for birds with different growth rates.
- Little information is available on the extent to which leg culling is implemented in the industry, or how long severely lame birds spend in this condition before being culled or dying.
- **Surveys on the prevalence of lameness in regions other than Europe, particularly in top chicken-producing countries (e.g., US, China, Brazil, India, Mexico, Argentina), are very much**

needed. Studies should strive to describe disaggregated data on the prevalence of birds within different gait scores, as opposed to calculated scores only.

- **No published data is available on the prevalence of birds in each gait score for slower-growing breeds raised in commercial conditions.** The only data available, disaggregated by gait score, is from experimental trials. Surveys of flocks kept in commercial conditions are critically needed.
- **The extent to which the onset of cardiorespiratory abnormalities is delayed in slower-growing birds is currently unknown.**
- **There is no recent data on the prevalence of mortality from ascites in commercial flocks,** neither for fast- nor slower-growing strains. Existing data is from experimental studies, or from small and old datasets. Surveys in the slaughter plant are available, but they depict an incomplete picture of the problem as they disregard on-farm and transport mortality. Likewise, recent information on the incidence of non-fatal cases of pulmonary hypertension in commercial flocks is currently lacking.
- The underlying causes of reduced feed intake in birds experiencing pulmonary hypertension are not fully understood. Lack of knowledge on whether it is due to a lack of appetite driven by metabolic changes or to feelings of discomfort makes it difficult to estimate the extent of suffering experienced by affected individuals.
- **Little is known about the strength of broilers' motivation to forage, perch and dustbathe.** Operant and preference testing would allow for a better understanding of the welfare impact of deprivation of these behavioral opportunities.
- **Data on the overnight behavior of broilers is limited,** hence knowledge of the welfare impacts of the inability to roost and the effects of rest disruption.
- **Longitudinal data on the proportion of birds affected by heat stress over the entire production cycle, as well as typical variations along the day and year, are much needed,** particularly outside Europe.
- To our knowledge, **there has been no research evaluating the degree of aversion that heat stress represents to broiler chickens.**
- Further **research on the extent to which chronic hunger is aversive in broiler breeders would be beneficial (e.g. demand elasticity or 'willingness to pay' tests).** Studies on this and other welfare challenges do not require exposing birds to any additional aversive experience, as they could be conducted with flocks already exposed to typical conditions (e.g. feed restriction) in commercial operations.
- **The extent to which published research on farm animal welfare is biased towards conditions of better welfare is unknown.** Currently, most research data is from northern European countries (where welfare legislation is stricter) and in many cases from facilities that volunteer or agree to participate in research studies (hence which may have better welfare standards). Studies in commercial operations outside Europe and policies aimed at facilitating access of researchers to commercial farms could be highly useful to provide a clearer picture of the conditions typically experienced by broiler chickens, their breeders and other farm animals.

IX. Acknowledgments

We are very grateful to Michael St. Jules for input and feedback.

X. References

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