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# Literature update on effective environmental enrichment and light provision in broiler chickens

C. Souza da Silva and I.C. de Jong

Report 1204



**WAGENINGEN**  
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Wageningen Livestock Research

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### **Summary**

The results of a literature study to the effect of different types of environmental enrichment and light conditions on broiler chickens welfare are described, in order to attempt to provide an environment to slow-growing broiler chickens that better meets their behavioural requirements. With respect to environmental enrichment, a review paper has been used as a starting point and more recent information has been collected and summarised. With respect to lighting, in consultation with stakeholders we chose to limit the literature study to a few potential interesting areas of research (e.g. natural light provision and its variation across the broiler house). There are several research questions in relation to enrichment provision, e.g., optimal perch design, multiple use of enrichments and the actual number of enrichments that should be provided. Currently, little is known about the need for light in slow-growing broiler chickens and how this interacts with the environmental enrichment offered. Future research priorities include the optimization of methods of natural light provision (which is often applied in higher welfare indoor systems with slow-growing breeds), testing effects of ultraviolet wavelengths on chicken behaviour, and light colour preferences in slow-growing breeds.

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# Foreword

The project '*Trager groeiende vleeskuikens: Op weg naar integraal duurzaam dierenwelzijn*' (*Slow growing broiler chickens: steps forward to an integral sustainable animal welfare*) is a public-private partnership between the Ministry of Agriculture, Nature and Food Quality, a consortium of various private parties and organizations within the slow growing broiler production chain and Wageningen Livestock Research. The project aims to contribute to a broader sustainable and healthy slow growing broiler chain in the Netherlands.

This report contains the results of a literature review and practical inventory of the available information about slow growing broilers in relation to their rearing environment, in order to meet their behavioural needs.

For the current study, scientists of Wageningen Livestock Research worked together with representatives from the consortium, and the authors thank the private partners of the project team for their worthwhile input.

Dr. R.A. (Rick) van Emous, project leader.





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# Summary

The ultimate goal of the project '*PPS Trager groeiende vleeskuikens: Op weg naar integraal duurzaam dierenwelzijn*' (*Slow growing broiler chickens: steps forward to an integral sustainable animal welfare*) is to offer an environment to slow-growing broiler chickens which meets their behavioural needs. As a starting point to define research questions specifically targeted to optimise housing conditions of these chickens, the current report was written to summarise the state-of-the art of knowledge with respect to effective environmental enrichment and lighting conditions used for slow-growing broiler chickens at the moment. With respect to environmental enrichment, the review paper of Riber and collaborators (2018) has been used as a starting point and more recent information has been collected and summarised. With respect to lighting, after consultation with stakeholders, the literature study has been narrowed to three potential interesting areas of research: (1) effects of natural light provision and its variation across the broiler house; (2) effects of ultraviolet wavelengths on chicken behaviour; and (3) light colour preferences of broiler chickens.

Elevated resting places (such as perches and platforms) are generally accepted as an effective form of enrichment for broiler chickens. Perch use varies, whereas platforms are often well used by slow-growing broiler chickens. Evaluation of optimal designs of perches should be considered in order to stimulate perch use, but the risk for increased prevalence of breast blisters and keel bone damage with perches should be also considered in slow-growing broiler chickens. Substrate bales are considered as a type of enrichment with multiple functions that have not been fully explored in broiler production systems yet. Birds may use bales for perching, for clustering around it (protection), and for explorative behaviour (pecking). To date, no studies have specifically documented the multiple uses of one enrichment. In addition, there are no scientifically proved indications of an optimum number of enrichments (such as bales and elevated resting places) per number of chickens that should be provided. Therefore, studies on multi-functional types of enrichments and on the optimum number of enrichments that should be provided in accordance to group size are highly recommended.

Currently, little is known about the need for light in slow-growing broiler chickens and how this interacts with the environmental enrichment offered. There are various potential interesting areas of research with regard to light, and some of these have been mentioned in the present report. One important issue regards the provision of natural light in the so-called higher welfare indoor systems used for slow-growing broiler chicken production in the Netherlands. It is unclear whether the methods of providing natural light really meet the need of all birds at all ages in these systems. There is also an important question about variation in natural light intensity across the broiler house that may stimulate birds to use different areas around the house for different behaviours, and this merits further research as well. Optimization of the method of providing natural light is also needed, and experiments testing differences between roof and side wall windows effects on broiler behaviour and welfare are encouraged. To date, there are no studies that have been conducted in the Netherlands to test effects of ultraviolet wavelengths on chicken behaviour and to test light colour preferences in slow-growing breeds. Thus, studies on ultraviolet wavelengths and colour preferences in slow-growing broilers in relation to age and behaviour are needed.

To conclude, in relation to the current lack of knowledge on the behavioural requirements of slow-growing broiler chickens, various questions were raised during the writing and discussion of the present report. In the next phase of the project in 2020 and beyond, a limited number of research questions will be selected and used for the design of experiments on enrichment provision and on light provision in slow-growing broiler chickens. Different slow-growing breeds are used nowadays, and may differ with regard to their requirements for enrichment and light. Nevertheless, the main focus of the experiments will be on Hubbard slow-growing breeds which are considered representative of the Dutch slow-growing broiler market at the moment.



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# 1 Introduction

In the Netherlands, the production of broiler chickens experienced a significant change between 2014 and 2016. This was due to the rapid introduction to all Dutch supermarkets of their own '*Kip van Morgen*' (*Chicken of tomorrow*) concept (Saatkamp, et al., 2019) in addition to the already existing '*Beter Leven*' (*Better life*) concept that was introduced by the Dutch Society for the Protection of Animals (SPA) in 2007. Both alternative production concepts are aimed at improving broiler welfare. As a result, currently around 35-40% of broiler chickens produced in the Netherlands are kept according to a slower-growing concept (Avined, 2019; Van Boekholt, pers. comm.). Slow-growing broiler chickens are defined as broiler chickens produced by slow-growing female parent stock that are crossed with a regular or slow-growing male. These broiler breeds are either accredited by the Dutch SPA with the '*Beter Leven*' quality label (maximum average daily growth of 45 grams) or fall within the standards of the original '*Kip van Morgen*' concept (maximum average daily growth of 50 grams) (Ellen, et al., 2012; Saatkamp, et al., 2019). Based on the number of broiler breeders present in the Netherlands, it is estimated that the Hubbard breeds have a share of approximately 75% of the total slow-growing broiler market (Van Boekholt, pers. comm.), and are considered representative of the Dutch slow-growing broiler market at the moment.

With regard to animal welfare, it is important that farm animals are kept in an environment that meets their behavioural needs. The possibilities to perform natural behaviour are an essential part of animal welfare and contribute to the animal's experiencing positive emotions (Welfare Quality, 2009; Boissy, et al., 2007; Fraser, 1995). Chickens are day-active animals that spend a large part of the light period gathering food and being active (Dawkins, 1989). Also, chickens are intelligent animals that need cognitive challenges and actively collect information from their environment (Marino, 2017). The visual spectrum of the chicken is larger than that of humans, and the type of light that is provided determines how a chicken experiences the environment (Prescott and Wathes, 1999). Therefore, a greater variety in environmental enrichment and light, than is currently applied in commercial broiler houses, is expected to better meet the behavioural needs of broiler chickens. However, further research is still needed, particularly in recently introduced slow-growing breeds.

Effective environmental enrichment stimulates natural behaviour, can reduce negative feelings such as anxiety, and contributes to experiencing positive emotions (Riber, et al., 2018) and thus potentially contributes to broiler chickens' welfare. Although much research is currently being done on effective environmental enrichment for broiler chickens, the majority of previous and current research focused on regular, fast-growing breeds (Bailie, et al., 2013; Bailie, et al., 2018a; Bailie, et al., 2018b; Bailie and O'Connell, 2014; Baxter, et al., 2018b; Baxter, et al., 2019; De Jong and Gunnink, 2019; Riber, et al., 2018). A one-to-one translation of effects of environmental enrichment on behaviour and other welfare indicators of fast-growing broiler chickens into slow-growing breeds is not possible, because the behavioural needs of slow-growing breeds may differ, and they are usually much more active and have a different time budget than fast-growing broiler chickens (Bokkers and Koene, 2003; Rothschild, et al., 2019). Slow-growing broiler chickens are less affected by their body weight, body shape and locomotion problems than fast-growing broiler chickens when conducting behaviour, especially in the last weeks prior to slaughter (EFSA, 2010). Thus, both the need for specific environmental enrichment as well as the effects of environmental enrichment on behaviour and other welfare indicators may differ between fast and slow-growing broiler chickens.

Currently, little is known about the need for light in broiler chickens - both in terms of intensity and spectrum, and how this interacts with the environmental enrichment offered. Broilers may, for instance, have preferences to perform specific behaviours under different light and enrichment conditions. This applies to both fast- and slow-growing broiler chickens, but the few research that has been conducted has been done on fast-growing chickens (Archer, 2018; Huth and Archer, 2015; Riber, 2015). Light intensity and wavelengths provided in current housing systems for broiler chickens, including the provision of natural light (daylight), are usually based on perceptions or knowledge from laying hens or fast-growing broiler chickens. More insight in the specific requirements

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of slow-growing broiler chickens with respect to light helps to provide housing conditions that better meet the needs of the birds, and thus contribute to broiler chickens' welfare.

In the current report, we aim to summarise the state-of-the art of knowledge with respect to effective environmental enrichment and lighting conditions for broiler chickens, as a starting point to define research questions specifically targeted to optimise housing conditions for slow-growing broiler chickens. With respect to environmental enrichment, the publication of Riber and collaborators (Riber, et al., 2018) has been used as a starting point and more recent information has been collected and summarised. With respect to lighting, in consultation with stakeholders we chose to limit the literature study to three potential interesting areas of research: (1) effects of natural light provision and its variation across the broiler house; (2) effects of ultraviolet wavelengths (UV) on chicken behaviour; and (3) light colour preferences of broiler chickens. The reasoning behind these choices is that currently many housing systems for slow-growing broiler breeds include the provision of natural light, but it is unclear whether the methods of providing natural light really meet the need of all birds at all ages. There is also an important question about variation in natural light provision across the broiler house. For example, in UK houses light is often provided in windows along the side of the house. This means that there is variation in light intensity across the house, so that birds can utilise different areas around the house for different behaviours. Broiler chickens prefer low light intensities for resting and high light intensities for active behaviours (Blatchford, et al., 2012; Rault, et al., 2017). Currently, roof windows (without shutters) provided in broiler houses do not always allow for much variation, which means that light distribution is quite uniform. Thus, individual birds do not always have the opportunity to choose to perform different behaviours at different areas (Rayner, pers. comm.). With respect to UV<sub>A</sub>, this affects the bird's perception of the environment and may have positive effects on behaviour and welfare (Niekerk, et al., 2015). Moreover, with the increased use of light-emitting diode (LED) lights in poultry housing, broilers can be provided with different light colours depending on the age, time of the day and functional area in the house, but more insight is needed in the actual colour preferences of the chickens (Archer, 2018; Riber, 2015).

The final aim of the project '*PPS Trager groeiende vleeskuikens: Op weg naar integraal duurzaam dierenwelzijn*' (*Slow growing broiler chickens: steps forward to an integral sustainable animal welfare*) is to offer an environment to slow-growing broiler chickens which meets their behavioural needs, e.g. for exploration, free-range use, dustbathing, foraging behaviour, resting behaviour, and promotes positive experiences, and, thus, limits the risk for negative emotions such as fearfulness. This to optimise their welfare in commercial systems, while at the same time being practically applicable and economically efficient. Therefore, this literature study and practical inventory form the basis for trials in 2020 and beyond.

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## 2 Materials and methods

### 2.1 Literature study environmental enrichment

The present literature study is based on the review paper from Riber and collaborators (Riber, et al., 2018), which gives an overview of the different kinds of environmental enrichment in all types of production systems for broiler chickens. The review was based on relevant scientific literature from the database "Web of Science" retrieved using the key words "broiler environmental enrichment." In addition, the review includes references identified on reference lists of papers reviewed. With the exception of a few textbook sources and scientific reports, only peer-reviewed references have been included, written in English or German. The time frame for inclusion into the review was that sources were published in or after the year 2000, up until year 2017.

For the purpose of section 4.1 (Behavioural needs) of the project *PPS Trager groeiende vleeskuikens: Op weg naar integraal duurzaam dierenwelzijn* (2019) - which is to gain insight into the needs of slow-growing chickens with regard to environmental enrichment and light provision - the summary tables included in the paper of Riber and collaborators (Riber, et al., 2018) were expanded with relevant scientific literature published in or after the year 2017, up until year 2019. Most references were retrieved from the database "Web of Science" on June 3-5, 2019, using the same key words as in the paper of Riber and collaborators (Riber, et al., 2018). Moreover, two extra scientific reports have been included: one pilot-study report from Wageningen Livestock Research (De Jong and Van Wijhe-Kiezebrink, 2014) and a recently finished Master thesis report from Wageningen University and Research (Blaauw, 2019).

### 2.2 Literature study light provision

In consultation with stakeholders we chose to limit the literature study to three potential interesting areas of research: (1) effects of natural light provision and its variation across the broiler house; (2) effects of ultraviolet wavelengths on chicken behaviour; and (3) light colour preferences of broiler chickens. These topics and peer-reviewed references included in the present literature study were selected after personal communication with Kim Geurts (HATO Agricultural Lighting, Sittard, The Netherlands) and Annie Rayner (FAI Farms, Oxford, UK). Older scientific literature that has been published on the effects of light conditions (particularly light colour) on growth performance parameters of broiler chickens have not been included in the present literature study because it falls outside the scope of the study.

### 2.3 Practical inventory

In addition, a practical inventory was carried out with the help of stakeholders (Janny Hermans from AdVee Veterinary Practice, Ysselsteyn, The Netherlands and Henk-Jan Schuurman from De Hoop Mengvoeders B.V., Zelhém, The Netherlands) with regard to environmental enrichment and natural light provision, yielding a list of enrichments that are applied in practice, and the methods of providing natural daylight to slow-growing broiler chickens in the Netherlands. Moreover, after an open plenary discussion of the present report with all project partners, the practical inventory sessions have been further expanded.

# 3 Results on Environmental Enrichment

## 3.1 Literature study

### 3.1.1 Point-Source Objects in Conventional Environments

The following types of point-source objects used in conventional environments are reviewed in this section: perches and platforms; panels, barriers and bales of substrates; materials and methods stimulating foraging and dustbathing behaviour; and novel objects.

#### 3.1.1.1 Perches and Platforms

Table 1 presents the main features of the perches and platforms used in the studies reviewed by Riber and collaborators (Riber, et al., 2018), updated with results from recent publications.

**Table 1** *Perch and platform design for broilers used in different studies. Adapted from Riber and collaborators (Riber, et al., 2018). Information written in bold correspond to literature published in or after the year 2017, which were added to the original table of Riber and collaborators (N/A = information not available).*

Reference	Material	Design			Genotype		Stocking density
		Height above ground	Dimensions (length × width × depth OR length, Ø)	Shape and access ramp	Slow-growing	Fast-growing	
Aksit, et al., 2017	Galvanized steel pipes	15cm	200cm, Ø2cm	-		Ross 308	14 birds/m <sup>2</sup>
Bailie and O'Connell, 2015	Supported wooden beam	15cm	300 × 5 × 5cm	Rounded upper edge	-	Ross 308	17 birds/m <sup>2</sup> (but not exceeding 30 kg/m <sup>2</sup> )
Bailie and O'Connell, 2016; Bailie, et al., 2018a	<b>Elevated plastic (mesh) platform</b>	<b>66 cm (above litter)</b>	<b>240 x 60 cm</b>	<b>(1) A-frame design (incorporating a platform and ramps)</b>	-	<b>Ross 308</b>	<b>Cycle 1=12 birds/m<sup>2</sup>, Cycle 2=17 birds/m<sup>2</sup></b>
	<b>Elevated plastic (mesh) platform</b>	<b>66 cm (above litter)</b>	<b>59 x 59 cm</b>	<b>(2) 'flat top' ramp</b>			
	<b>Rectangle of wire mesh which was bent</b>	<b>32 cm (above litter)</b>	<b>5 x 98 cm</b>	<b>(3) curved ramp</b>			
	<b>Wooden beams</b>	<b>Week 2: 5 cm, week 3: 10 cm, week 4: 15 cm, week 5: 20 cm</b>	<b>300 x 4 cm</b>	<b>(4) suspended bar</b>			
	<b>Wooden beams</b>	<b>15 cm</b>	<b>300 x 4 cm</b>	<b>(5) fixed bar</b>			

Reference	Material	Design			Genotype		Stocking density
		Height above ground	Dimensions (length × width × depth OR length, Ø)	Shape and access ramp	Slow-growing	Fast-growing	
	<b>Elevated plastic (mesh) platform</b>	<b>Week 2: 5 cm, week 3: 10 cm, week 4: 15 cm, week 5: 20 cm</b>	<b>240 x 60 cm</b>	<b>(6) suspended platform</b>			
<b>Baxter, et al., 2019</b>	<b>Elevated plastic (mesh) platform</b>	<b>20 cm (above litter)</b>	<b>230 x 90 cm</b>	<b>Without ramp</b>	<b>-</b>	<b>Ross 308</b>	<b>N/A</b>
<b>Bench, et al., 2017</b>	<b>Wooden beams</b>	<b>10 cm</b>	<b>185 x 5 x 10 cm</b>	<b>Without ramp, perch types: I-shape and X-shape</b>	<b>-</b>	<b>Ross 308</b>	<b>13.47 birds/m2</b>
<b>Berghout, et al., 2018</b>	<b>Wooden beams</b>	<b>6, 20 and 35.5 cm</b>	<b>127 x 109.5 cm, Ø 6 cm</b>	<b>A-frame with oval shaped perches</b>	<b>-</b>	<b>Ross 308</b>	<b>21-23 birds/m2 (42 kg/m2)</b>
	<b>Elevated plastic platforms</b>	<b>9.5 and 14 cm</b>	<b>36 x 56 cm</b>	<b>Without ramp, platforms created by placing plastic transport crates upside down in the litter</b>			
<b>Bergmann, et al., 2017</b>	<b>PVC pipes</b>	<b>N/A</b>	<b>103 m, Ø ? cm</b>	<b>Rounded upper edge, coated with an antiskid material</b>	<b>Cobb Sasso 175</b>	<b>Ross 308</b>	<b>16 birds/m2</b>
Bizeray, et al., 2002b	Wooden beams	15cm	100/150 × 4 × 15cm	-	-	Ross 308	10 birds/m2
<b>Blaauw, 2019</b>	<b>Elevated wooden platform</b>	<b>40 cm</b>	<b>100 x 20 cm</b>	<b>Ramps with 11.5° angles</b>	<b>Hubbard JA 757</b>	<b>Ross 308</b>	<b>10 birds/m2</b>
	<b>Wooden beams</b>	<b>4 cm at day 0, 8 cm at day 8, 12 cm at day 14, 16 cm from day 21 onwards</b>	<b>100 x 4 x ? cm</b>	<b>Barrier-perch</b>			
Bokkers and Koene, 2003	Wooden slat	10cm	80 × 5 × 5cm	Rounded upper edge	JA 657*	HI-Y (Hubbard)	4 birds/m2

Reference	Material	Design			Genotype		Stocking density
		Height above ground	Dimensions (length × width × depth OR length, Ø)	Shape and access ramp	Slow-growing	Fast-growing	
De Jong and Van Wijhe-Kiezebrink, 2014	Elevated plastic (mesh) platform	25 cm (low platform), and 50 cm (high platform)	100 x 100 cm (low platform), and 500 x 100 cm (high platform)	-	Hubbard JA 757	-	13 birds/m <sup>2</sup>
	Metal pipe	25, 50 and 75 cm	280 x 110 cm	A-frame with perches			
De Jong and Gunnink, 2019	Metal pipe	5 cm at day 0, 15 cm at day 14, 20 cm at day 21, 25 cm at day 28, 35 cm from day 34 onwards	85 m, Ø5cm	Round	-	Ross 308	19.8 birds/m <sup>2</sup>
Groves and Muir, 2013	Wooden beams	15 and 30cm	100 × 4 × 4cm	-	-	N/A, BW at day 28: breed A 1590 g, breed B 1502 g	3.8 birds/m <sup>2</sup>
Estevez, et al., 2002	Iron pipes, cooled with 10° C water	15cm	456cm, Ø3.8cm	Round	-	Peterson × Cobb	13.43 birds/m <sup>2</sup>
	Iron pipes, cooled with 10° C water	7.5cm					
	Iron pipes	15cm					
Kaukonen, et al., 2016; Kaukonen, et al., 2017	Elevated plastic platforms	30 cm	360 × 60cm	Ramps with 15° angles	-	Ross 508	16 birds/m <sup>2</sup>
	Wooden beams	10 and 30 cm	200 × 5 × 5cm or 200 × 2.2 × 2.2cm	Rounded upper edge			
LeVan, et al., 2000	PVC pipes	8.5cm	91cm (main bar), 28 cm	Without ramp, round	-	Avian x Avian	11.11 birds/m <sup>2</sup>
		17cm	(crossbar), Ø2.6cm	Ramps with 10° angle, round			
		35.5cm		Ramps with 20° angles, round			
Malchow, et al., 2019	Elevated plastic (mesh) platforms	10, 30, 50 cm	90 × 30 cm	One ramp (width: 20 cm,	Lohmann Dual (medium-	Ross 308	8 birds/m <sup>2</sup>



Reference	Material	Design			Genotype		Stocking density
		Height above ground	Dimensions (length × width × depth OR length, Ø)	Shape and access ramp	Slow-growing	Fast-growing	
				<b>inclination angle: 35°)</b>	<b>growing);</b>		
				<b>installed in between the platforms</b>	<b>Lohmann Brown Classic (slow-growing)</b>		
Martrenchar, et al., 2000	Wooden beams	20 and 33cm	200/400 × 3.5 × 5cm	Rounded upper edge	-	Ross <sup>1</sup>	Exp. 1: 11 or 22 broilers/m <sup>2</sup> Exp. 2 & 3: 17 broilers/m <sup>2</sup>
Nielsen, 2004	Wooden beams	40, 65, 90, 115 and 140cm	75 × 5.7 × 3.8cm	-	i657 Labresse	-	6 birds/m <sup>2</sup>
Norring, et al., 2016	Elevated plastic platforms	30cm	360 × 60cm	Ramps with 15° angles	-	Ross 508	16 birds/m <sup>2</sup>
	Wooden perches	10cm 30cm	200 × 5 × 5cm or 200 × 2.2 × 2.2cm	Rounded upper edge			
Pettit-Riley and Estevez, 2001	PVC pipes	8.5cm 17cm (max) 35.5cm (max)	91cm (main bar), 28 cm (crossbar), Ø2.6cm	Without ramp, 0° angle, round Ramps with 10° angle, round Ramps with 20° angle, round	-	Avian x Avian	10, 15 and 20 broilers/m <sup>2</sup>
Pettit-Riley, et al., 2002	PVC pipes	8.5cm 17cm (max) 35.5cm (max)	91cm (main bar), 28 cm (crossbar), Ø2.6cm	Without ramp, 0° angle, round Ramps with 10° angle, round Mixed: 0°, 10°, and 20° angle, round		Avian x Avian	10, 15 and 20 broilers/m <sup>2</sup>
<b>Rodriguez-Aurrekoetxea, et al., 2014;</b> <b>Rodriguez-Aurrekoetxea, et al., 2015</b>	<b>Wooden beams</b>	<b>25 cm</b>	<b>50 x 4 x 25 cm</b>	<b>-</b>	<b>Sasso T44</b>	<b>-</b>	<b>Indoor: 12 birds/m<sup>2</sup>, Outdoor: 2 birds/m<sup>2</sup></b>
Sandilands, et al., 2009	Wooden beams	N/A	150cm × ? × ?	A-frame with 42° angles A-frame with 12° angles, wire ramps	-	Ross 308	N/A
Su, et al., 2000	Wooden beams	Weeks 0-2: 10cm, weeks 2-6: 25cm	? × 3.5 × 2.5cm ?, Ø1.5cm	-	-	Ross 208	18 birds/m <sup>2</sup>
<b>Tahamtani, et al., 2018<sup>2</sup></b>	<b>Elevated plastic platforms</b>	<b>30cm</b> <b>5 cm</b>	<b>540 × 60cm</b> <b>540 x 60 cm</b>	<b>Ramps with 14.5° angles</b> <b>-</b>	<b>-</b>	<b>Ross 308</b>	<b>16.5 birds/m<sup>2</sup></b>

Reference	Material	Design			Genotype		Stocking density
		Height above ground	Dimensions (length × width × depth OR length, Ø)	Shape and access ramp	Slow-growing	Fast-growing	
<b>Vasdal, et al., 2019</b>	<b>Elevated plastic platforms</b>	<b>48 cm</b>	<b>480 x 60 cm</b>	<b>Ramps with 23.6° angles</b>	-	<b>Ross 308</b>	<b>Flock 1=16.5 birds/m<sup>2</sup>, Flock 2=16.6 birds/m<sup>2</sup></b>
Ventura, et al., 2010	Wooden beams	10cm	100 × 4 × 15cm 100 × 4 × 15cm and 20 × 4 × 15cm	Simple barrier: I-shape Complex barrier: E-shape	-	Ross 308	8, 13 and 18 birds/m <sup>2</sup>
Ventura, et al., 2012	Wooden beams	10cm	100 × 4 × 15cm 100 × 4 × 15cm and 20 × 4 × 15cm	Simple barrier: I-shape Complex barrier: E-shape	-	Ross 308	8, 13 and 18 birds/m <sup>2</sup>
<b>Yildirim and Taskin, 2017</b>	<b>Wooden beams</b>	<b>30 cm</b>	<b>120 cm (main bar)</b>	<b>Ramps with 13° angles</b>	-	<b>Ross 308</b>	<b>10 birds/m<sup>2</sup></b>
Yngvesson, et al., 2016	N/A	N/A	N/A	-	Rowan Ranger Hubbard CYJA57	Ross 308	N/A
Zhao, et al., 2013	Iron pipes, cooled with 10° C water	N/A	N/A	-	-	Arbor Acres	12, 16 and 20 birds/m <sup>2</sup>

<sup>1</sup> Genotype not specified further.

<sup>2</sup> The conference article of Pedersen and collaborators (Pedersen, et al., 2017) was removed from the table of Riber and collaborators (Riber, et al., 2018) and replaced by the peer-reviewed article of Tahamtani and collaborators (Tahamtani, et al., 2018), which contains similar information that was already partly published in Pedersen et al. (2017).

\* Growth period 10 weeks

### 3.1.1.2 Panels, Barriers, and Bales of Substrate

Table 2 presents the main features of the panels, barriers, and bales of substrates used in the studies reviewed by Riber and collaborators (Riber, et al., 2018), updated with results from recent publications.

**Table 2** Panel, barrier, and substrate bale design for broilers used in different studies. Adapted from Riber and collaborators (Riber, et al., 2018). Information written in bold correspond to literature published in or after the year 2017, which were added to the original table of Riber and collaborators (N/A = information not available).

Reference	Material	Design			Location/ Quantity provided	Genotype		Stocking density
		Height	Dimensions (length × width)	Style		Slow-growing	Fast-growing	
<b>PANELS</b>								
Cornetto and Estevez, 2001a	Frame: white PVC, Mesh: black plastic	61cm	61 × 2cm	Frame with mesh	Centre of house	-	Avian × Avian	9 and 12.3 birds/m <sup>2</sup>
	Frame: white PVC			Frame without mesh				
Cornetto and Estevez, 2001b	Frame: white PVC, Mesh: black plastic	61cm	61 × 2cm	Frame with mesh	Centre of house	-	N/A, BW at day 44: 2.10 kg	9 and 12.3 birds/m <sup>2</sup>
	Frame: white PVC			Frame without mesh				
Cornetto, et al., 2002	Frame: white PVC, Mesh: black plastic	61cm	61 × 2cm	Frame with mesh	Centre of house	-	N/A, BW at day 44: 2.10 kg	9 and 12.3 birds/m <sup>2</sup>
	Frame: white PVC			Frame without mesh				
<b>Rodriguez-Aurrekoetxea, et al., 2014; Rodriguez-Aurrekoetxea, et al., 2015</b>	<b>Frame: white PVC, Mesh: green plastic</b>	<b>50cm</b>	<b>50 × 2.5cm</b>	<b>Frame with mesh</b>	<b>Centre of house and outdoor area</b>	<b>Sasso T44</b>	<b>-</b>	<b>Indoor: 12 birds/m<sup>2</sup>, Outdoor: 2 birds/m<sup>2</sup></b>
<b>Tahamtani, et al., 2018</b>	<b>N/A</b>	<b>60 cm</b>	<b>60 × ? cm</b>	<b>Opaque vertical panels</b>	<b>Centre of house</b>	<b>-</b>	<b>Ross 308</b>	<b>16.5 birds/m<sup>2</sup></b>
<b>BARRIERS</b>								
<b>Bench, et al., 2017</b>	<b>Wooden beams</b>	<b>10 cm</b>	<b>185 × 5 cm</b>	<b>types: I-shape and X-shape</b>	<b>N/A, two barrier perches per pen</b>	<b>-</b>	<b>Ross 308</b>	<b>13.47 birds/ m<sup>2</sup></b>
Bizeray, et al., 2002a	Wooden beams	9cm*	100 × 4cm and 150 × 4cm	-	Between feed and water	-	Ross 308	10 birds/m <sup>2</sup>
Ventura, et al., 2010	Wooden beams	10cm*	100 × 4cm and 150 × 4cm	Simple barrier: I-shape	Between feed and water	-	Ross 308	8, 13 and 18 birds/m <sup>2</sup>
			100 × 4cm and 20 × 4cm	Complex barrier: E-shape				
Ventura, et al., 2012	Wooden beams	10cm*	100 × 4cm	Simple barrier: I-shape	Between feed and water	-	Ross 308	8, 13 and 18 birds/m <sup>2</sup>

Reference	Material	Design			Location/ Quantity provided	Genotype		Stocking density
		Height	Dimensions (length × width)	Style		Slow-growing	Fast-growing	
			100 × 4cm and 20 × 4cm	Complex barrier: E-shape				
SUBSTRATE								
BALES								
Bailie, et al., 2013	Wheat straw	40cm	80 × 40cm	Bale edges wrapped in plastic	Dispersed evenly, 1 bale/44 m <sup>2</sup>	-	Ross	17 birds/m <sup>2</sup> (but not exceeding 30 kg/m <sup>2</sup> )
Bailie and O'Connell, 2014	Wheat straw	40cm	80 × 40cm	Bale edges wrapped in plastic	Dispersed evenly, 1 bale/44 m <sup>2</sup> Dispersed evenly, 1 bale/29 m <sup>2</sup>	-	Ross and Cobb <sup>1</sup>	17 birds/m <sup>2</sup> (but not exceeding 30 kg/m <sup>2</sup> )
<b>Baxter, et al., 2018b</b>	<b>Straw</b>	<b>40 cm</b>	<b>80 x 40 cm</b>	<b>Bale edges wrapped in plastic</b>	<b>Dispersed evenly, 1 bale/155 m<sup>2</sup></b>	<b>-</b>	<b>Ross 308</b>	<b>16 birds/m<sup>2</sup></b>
<b>Baxter and O'Connell, 2019</b>	<b>Straw</b>	<b>N/A</b>	<b>N/A</b>	<b>Bale edges wrapped in plastic</b>	<b>Dispersed evenly, 1 bale/143 m<sup>2</sup>, 3 bales placed in an L-shape (creating a semi-enclosed area)</b>	<b>-</b>	<b>Ross 308</b>	<b>16 birds/m<sup>2</sup> (but not exceeding 30 kg/m<sup>2</sup>)</b>
<b>Bergmann, et al., 2017</b>	<b>Straw</b>	<b>N/A</b>	<b>N/A</b>	<b>Bale edges wrapped in plastic</b>	<b>Dispersed evenly, 1 bale/37 m<sup>2</sup></b>	<b>Cobb Sasso 175</b>	<b>Ross 308</b>	<b>16 birds/m<sup>2</sup></b>
<b>Berghout, et al., 2018</b>	<b>Lucerne</b>	<b>N/A</b>	<b>N/A, 200 L bales</b>	<b>Plastic-wrapped</b>	<b>Dispersed evenly, 1 bale/500 birds</b>	<b>-</b>	<b>Ross 308</b>	<b>21-23 birds/m<sup>2</sup> (42 kg/m<sup>2</sup>)</b>
	<b>Wood shavings</b>	<b>N/A</b>	<b>N/A, 800 L bales</b>	<b>Plastic-wrapped</b>	<b>Dispersed evenly, 1 bale/500 birds</b>			
<b>De Jong and Van Wijhe-Kiezebrink, 2014</b>	<b>Lucerne</b>	<b>25 or 50 cm</b>	<b>42 x 55 cm</b>	<b>Bales placed in a rack</b>	<b>Dispersed in one section (quarter) of the house<sup>1</sup>, 1 bale/200 m<sup>2</sup></b>	<b>Hubbard JA 757</b>	<b>-</b>	<b>13 birds/m<sup>2</sup></b>
<b>De Jong and Gunnink, 2019</b>	<b>Wood shavings</b>	<b>N/A</b>	<b>N/A, 10 kg bales</b>	<b>Plastic-wrapped (but partly opened)</b>	<b>Dispersed evenly, 1 bale/34 m<sup>2</sup></b>	<b>-</b>	<b>Ross 308</b>	<b>19.8 birds/m<sup>2</sup></b>
Kells, et al., 2001	Straw	30cm	75 × 35cm	-	1 bale/17 m <sup>2</sup>	-	Ross and Cobb	N/A
<b>Tahamtani, et al., 2018</b>	<b>Straw</b>	<b>42 cm</b>	<b>122 x 48 cm</b>	<b>-</b>	<b>Dispersed evenly, 1 bale/10 m<sup>2</sup></b>	<b>-</b>	<b>Ross 308</b>	<b>16.5 birds/m<sup>2</sup></b>
<b>Vasdal, et al., 2019</b>	<b>Lucerne and peat</b>	<b>N/A</b>	<b>N/A, 150 L bales of peat</b>	<b>Plastic-wrapped (but partly opened)</b>	<b>Dispersed evenly, 1 bale/67 m<sup>2</sup></b>	<b>-</b>	<b>Ross 308</b>	<b>Flock 1=16.5 birds/m<sup>2</sup>, Flock 2=16.6 birds/m<sup>2</sup></b>

<sup>1</sup> Four types of enrichment were installed in the house, each enrichment in one section (quarter) of the house.

### 3.1.1.3 Materials and Methods Stimulating Foraging and Dustbathing Behaviour

#### Foraging substrates

Table 3 presents the main features of foraging substrates used in the studies reviewed by Riber and collaborators (Riber, et al., 2018), updated with results from recent publications.

**Table 3** Foraging substrates for broilers used in different studies. This table was created based on information from Riber and collaborators (Riber, et al., 2018). Information written in bold correspond to literature published in or after the year 2017, which were not present in the review of Riber and collaborators (N/A = information not available).

Reference	Feed supplement	Location	Quantity provided	Frequency	Genotype		Stocking density
					Slow-growing	Fast-growing	
Bizeray, et al, 2002a	Whole wheat	Scattered in the litter substrate	10 g per bird per day	Twice daily from day 8 to 17 (08:00 and 11:30 h)	-	Ross 308	10 birds/m <sup>2</sup>
<b>Blaauw, 2019</b>	<b>Black soldier fly larvae</b>	<b>Scattered in the dustbathing substrate</b>	<b>5% of the expected feed intake from day 8</b>	<b>Once daily from day 0 (11:00 h)</b>	<b>Hubbard JA 757</b>	<b>Ross 308</b>	<b>10 birds/m<sup>2</sup></b>
<b>De Jong and Van Wijhe-Kiezebrink, 2014</b>	<b>Maize</b>	<b>Scattered in the litter substrate</b>	<b>N/A</b>	<b>Once daily (09:00 h)</b>	<b>Hubbard JA 757</b>	<b>-</b>	<b>13 birds/m<sup>2</sup></b>
Jordan, et al., 2011	Whole wheat	Scattered in the litter substrate	1 to 8 g per bird from day 3 to 39 (the 1 <sup>st</sup> week 1 g/bird, in the 2 <sup>nd</sup> 2 g/bird, then increased by 2 g/bird each next week up to 8 g)	Twice daily from day 3 (06:00 and 18:00 h)	-	Ross 308	16 birds/m <sup>2</sup>
	Feed pellets	Scattered in the litter substrate	The daily quantity of pelleted grower, which was calculated	From day 14, 5 equal portions (06:00, 10:00, 14:00, 18:00 and 22:00 h)			
Pichova, et al., 2016	Whole wheat, wood shavings and mealworms	Scattered in the litter substrate	100 ml (per pen)	Once daily from day 6 (between 09:00 h and 14:00 h)	-	Ross 308	10 birds/m <sup>2</sup>
<b>Tahamtani, et al., 2018</b>	<b>Maize roughage</b>	<b>In three circular pans (ø 0.4 m), distributed evenly across the pen.</b>	<b>N/A</b>	<b>Once daily throughout the broilers' life</b>	<b>-</b>	<b>Ross 308</b>	<b>16.5 birds/m<sup>2</sup></b>

## Dustbathing substrates

Table 4 presents the main features of dustbathing substrates used in the studies reviewed by Riber and collaborators (Riber, et al., 2018), updated with results from recent publications.

**Table 4** *Dustbathing substrates for broilers used in different studies. This table was created based on information from Riber and collaborators (Riber, et al., 2018). Information written in bold correspond to literature published in or after the year 2017, which were not present in the review of Riber and collaborators (N/A = information not available).*

Reference	Dustbathing substrate	Location	Quantity provided and/or depth	Frequency of refill	Genotype		Stocking density
					Slow-growing	Fast-growing	
Baxter and O'Connell, 2016; <b>Baxter, et al., 2018a</b>	<b>Irish moss-peat (P), oat hulls (OH), straw pellets (SP) or wood shavings (WS).</b>	<b>In stainless steel rings (1.1 m diameter, 7.6 cm deep)</b>	<b>N/A</b>	<b>Refilled throughout the study when more than half of the substrate was gone</b>	-	<b>Ross 308</b>	<b>16 birds/m<sup>2</sup></b>
<b>Baxter, et al., 2018b</b>	<b>Oat hulls</b>	<b>In stainless steel rings (1 per 155 m<sup>2</sup>; 1.1 m diameter, 7.6 cm deep), with an area of 0.95 m<sup>2</sup></b>	<b>Initially 9 kg</b>	<b>Refilled throughout the study when more than half of the substrate was gone</b>	-	<b>Ross 308</b>	<b>16 birds/m<sup>2</sup></b>
<b>Baxter and O'Connell, 2019</b>	<b>Oat hulls</b>	<b>In stainless steel rings (1.1 m diameter, 7.62 cm deep), with an area of 0.95 m<sup>2</sup></b>	<b>Initially 14 kg, depth of about 5 cm</b>	<b>Refilled twice a week throughout the study</b>	-	<b>Ross 308</b>	<b>16 birds/m<sup>2</sup> (but not exceeding 30 kg/m<sup>2</sup>)</b>
<b>Baxter, et al., 2019</b>	<b>Moss-peat</b>	<b>In steel rectangles (1 x 2.3 m, 7.62 cm deep), with a total area of 9.2m<sup>2</sup>/house</b>	<b>Initially 160 l, depth of about 5 cm</b>	<b>Refilled twice a week throughout the study</b>	-	<b>Ross 308</b>	<b>16.5 birds/m<sup>2</sup></b>
<b>Blaauw, 2019</b>	<b>Moss-peat</b>	<b>In wooden squares (1 m x 1 m) located at the central area of the pen</b>	<b>Depth of 2 cm in week 1, 4 cm in week 2, and 7.5 cm from week 3 onwards</b>	<b>Refilled as needed</b>	<b>Hubbard JA 757</b>	<b>Ross 308</b>	<b>10 birds/m<sup>2</sup></b>
<b>Vasdal, et al., 2019</b>	<b>Moss-peat</b>	<b>In wooden boxes (130 cm x 250 cm x 20 cm high)</b>	<b>Depth of 12 cm (400 L) of peat</b>	<b>Refilled as needed</b>	-	<b>Ross 308</b>	<b>Flock 1=16.5 birds/m<sup>2</sup>, Flock 2=16.6 birds/m<sup>2</sup></b>
<b>Yildirim and Taskin, 2017</b>	<b>Sand</b>	<b>10 cm deep, 40-cm diameter plastic black container</b>	<b>N/A</b>	<b>N/A</b>	-	<b>Ross 308</b>	<b>10 birds/m<sup>2</sup></b>

## Suspended strings

Table 5 presents the main features of suspended strings used in the studies reviewed by Riber and collaborators (Riber, et al., 2018), updated with results from recent publications.

**Table 5** *Suspended strings for broilers used in different studies. This table was created based on information from Riber and collaborators (Riber, et al., 2018). Information written in bold correspond to literature published in or after the year 2017, which were not present in the review of Riber and collaborators (N/A = information not available).*

Reference	Material	Dimensions	Location	Quantity provided	Genotype		Stocking density
					Slow-growing	Fast-growing	
Arnould, et al., 2004	White polypropylene	N/A	Hanging in the centre of the pen 1 cm above the head of a standing broiler; minimum distance between two strings = 10 cm	Six strings per pen, 6.6 broilers/string	-	PM3, Ross	3.3 birds/m <sup>2</sup>
Bailie and O'Connell, 2015	White nylon rope	60 cm x 10 mm, Height: 3 cm and then gradually raised to 20 cm above the litter	Close to the feed troughs	24 strings in a commercial flock of 23,000 broilers, 958 broilers/string	-	Ross 308	17 birds/m <sup>2</sup>
<b>Bailie, et al., 2018b</b>		<b>60 cm x 10 mm, Height: 33 cm and then gradually raised to 50 cm above the litter</b>	<b>Distributed as evenly as possible through the house</b>	<b>One string per 1,000 broilers/house</b>	-	<b>Ross 307</b>	<b>initial densities of 17, 18, 19, and 20 birds/m<sup>2</sup> (but not exceeding 36 kg/m<sup>2</sup>)</b>

## Pecking objects

Table 6 presents the main features of pecking objects used in recent studies reviewed in the current report. Thus, all information is supplementary to the review paper of Riber and collaborators (Riber, et al., 2018), which originally did not include a separate section on pecking objects.

**Table 6** *Pecking objects for broilers used in different studies. All information written in bold correspond to literature published in or after the year 2017, which were not present in the review of Riber and collaborators (N/A = information not available).*

Reference	Material	Dimensions	Location	Quantity provided	Genotype		Stocking density
					Slow-growing	Fast-growing	
Baxter and O'Connell, 2019	Black and yellow plastic-coated barrier chains	8 mm, cut to lengths of approximately 30 cm	Hung from the feeder lines, in three sections with two hanging chains per section	24 chains/house	-	Ross 308	16 birds/m <sup>2</sup> (but not exceeding 30 kg/m <sup>2</sup> )
Bergmann, et al., 2017	Pecking stones made of hard-pressed and	N/A	Dispersed evenly, 1 stone/60 m <sup>2</sup>	34 pecking stones/house (1.1 pecking	Cobb 175	Ross 308	16 birds/m <sup>2</sup>

Reference	Material	Dimensions	Location	Quantity provided	Genotype		Stocking density
					Slow-growing	Fast-growing	
	dried wheat bran			stones per 1000 birds)			
Berghout, et al., 2018	Pecking blocks	N/A	Dispersed evenly	1 block/500 birds	-	Ross 308	21-23 birds/m <sup>2</sup> (42 kg/m <sup>2</sup> )
	Plastic chains	N/A	Dispersed evenly, hung from the feeder lines	1 chain/500 birds			
De Jong and Van Wijhe-Kiezebrink, 2014	Pecking stones	12 cm diameter	Dispersed at equal distance of about 1.75 m in one section (quarter) of the house, 1 stone/160m <sup>2</sup>	10 pecking stones per section (quarter) of the house	-	Hubbard JA 757	13 birds/m <sup>2</sup>
De Jong and Gunnink, 2019	Metal chains	link size 20 x 18 mm, the end of the chains reached the floor	Attached to the two ventilation channels along the length of the house (equally distributed)	30 chains/house (1 chain per 1000 birds)	-	Ross 308	19.8 birds/m <sup>2</sup>
Yildirim and Taskin, 2017	Ball	Red plastic ball (10 cm diameter)	Suspended from overhead wires in such a way that they dangled from the pen ceiling	N/A	-	Ross 308	10 birds/m <sup>2</sup>
	Mirror	Double faced mirror (20 x 10 cm)		N/A			

#### 3.1.1.4 Novel objects

There are no references available after the year 2017.

To date, there was one study conducted to assess the effects of early environmental enrichment by addition of novel objects on growth performance, fearfulness and well-being of broiler chicks (Altan, et al., 2013). Altan and collaborators (2013) added a variety of novel objects, including coloured plastic balls, plastic bottles, toys, and mirrors, from d 0 to d 21 to experimental pens (50 broilers/pen) housing commercial broilers (genotype and number of objects not specified). All the objects were placed on the floor, except the mirrors, which were hung from the ceiling at chicks' eye level. Every third day the objects were replaced to avoid adaptation and maintain novelty.

#### 3.1.1.5 Summing up on Point-Source Enrichments

Table 7 summarizes the broilers' use of the different point-source enrichments reviewed and its effects on the prevalence of different welfare and production indicators measured. This table was created based on information from Riber and collaborators (Riber, et al., 2018) and literature published in or after the year 2017 taken all together in one table.

According to Riber and collaborators (Riber, et al., 2018), the opportunity to **perch** is utilized by broilers and will be suitable enrichment for both slow and fast-growing broilers. As such, it is an effective form of enrichment. In the original table of Riber and collaborators (Riber, et al., 2018), outcomes for animals (mostly fast-growing broilers) have been described as effects on leg/foot problems (reduced), heat stress (reduced), behaviour disturbances and aggression (reduced). The knowledge on the risk for breast blisters and keel bone damage is still low or unknown (Riber, et al., 2018). In the present table 7, some outcomes for animals have been described slightly different than in the original table of Riber and collaborators (Riber, et al., 2018). For example, the use of perches, in both fast and slow-growing broilers, was found to be low. This conclusion was based on 13 out of 20



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scientific publications reporting low use of perches in fast-growing broilers, and on 4 out of 6 scientific publications reporting low use of perches in slow-growing broilers. Particularly for the slow-growing broilers, the number of publications reporting on perch use is rather low (6 vs 20) as compared to the fast-growing broilers. In practice, slow-growing broilers seem to show much greater perch use compared to the standard fast-growing breeds (Rayner, pers. comm.). So, still more research is needed on perch use in slow-growing broilers. Also in table 7, general activity level was found to be increased in slow-growing broilers, whereas in fast-growing broilers the results were unclear, i.e. some studies show an increased activity level, and others do not. The majority of the literature reported no effects of perches on leg/foot health in both fast and slow-growing broilers. Nevertheless, in some literature perches were found to promote more even distribution of birds throughout the pen space in both fast and slow-growing broilers. Moreover, as already reported for fast-growers, perches do not seem to affect growth in the slow-growing broilers.

Although the use of perches was found to be low (particularly in fast-growing broilers), perching is considered an integral part of chicken behaviour, and is suggested to alleviate leg problems and enhance mobility in broilers, as it stimulates diversification of locomotion. Hence, there is still a need for investigation of elevated structures that are better accepted by broiler chickens (Norrington, et al., 2016). As already indicated by Riber and collaborators (Riber, et al., 2018), designing perches low and wide for better support of the broilers increases usage, and perching of up to 25% of daytime has been reported in their review. Perching material and how these are provided also determines the use (e.g., metal is not preferred by birds because it is slippery). Currently, there is more information available for laying hens (EFSA, 2015) which can be used as a basis for broiler chicken studies (De Jong, pers. comm.). In addition, usage of elevated resting places is also influenced by genotype, age, environmental temperature, flock size, and stocking density (Riber, et al., 2018). These aspects should be considered in the design of future experiments.

In table 7, the use of **platforms**, in both fast and slow-growing broilers, was found to be frequent. General activity level was found to be increased in slow-growing broilers, whereas in fast-growing broilers the results were unclear, i.e. some studies show an increased activity level, and others do not. In slow-growing broilers, the use of platforms seems to have little influence on leg/foot health, whereas in fast growing broilers results are unclear, i.e. some studies show reduced leg/foot problems, and others do not. Some studies reporting on platform use also indicate that the slope of the ramp (that gives access to the platform) may affect leg health in broilers. Nevertheless, this aspect has not been investigated in the present report, but it merits further research in both fast and slow-growing broilers. In fast-growing broilers, a few studies have reported positive effects of platforms on decreasing fearfulness and improving welfare (Baxter, et al., 2019; Tahamtani, et al., 2018). Moreover, as already reported for fast-growers, platforms do not seem to affect growth in the slow-growing broilers.

The frequent use of platforms indicates they are better suited for broilers than perches. However, platforms did not appear to always stimulate general activity, particularly in the fast-growing broilers. The fact that the broilers used platforms to a high degree indicate that broilers are motivated to use elevated structures or driven by high animal densities. But it has been shown by De Jong and Göertz that platforms may be well used even with low stocking densities (De Jong and Göertz, 2017). It might be that the low perch use is due to physical challenges and not to a lack of motivation to use elevated structures (Norrington, et al., 2016).

According to Riber and collaborators (Riber, et al., 2018), platforms offer additional possibilities for locomotion. It is possible that broilers make better use of these types of elevated resting places as compared to perches, as raised platforms will be easier to access and heavy birds may have fewer problems with finding their balance when resting. However, there is still very limited scientific knowledge, particularly in slow-growing broilers, about the effects of such resting places on behaviour and other welfare aspects. As for the perches, there is still research needed on the optimum height, dimensions and material used in platforms and ramps for slow-growing broilers.

**Panels, barriers, and bales** (either straw, lucerne hay or wood-shavings) are all types of environmental enrichment that broilers use for perching or for a quiet resting area to lie against with

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reduced disturbance, and as such, can be effective enrichment (Riber, et al., 2018). Particularly bales are well used by both fast and slow-growing broilers (table 7). It should be highlighted that bales are used in terms of both perching and clustering around the bales, therefore they provide additional benefits above just providing an elevated resting space (De Jong and Gunnink, 2019). To date, no studies have specifically documented the multiple uses of one enrichment, which could be considered as providing for multiple behavioural needs of broilers. So, this merits further research in both fast and slow-growing broilers. Furthermore, panels and barriers can contribute to a more even distribution of birds in the house, which ameliorates potential localized problems associated with high stocking densities. Nevertheless, scientific knowledge is unclear about effects of these objects on leg/foot health and on activity (Riber, et al., 2018). Recently, a few studies have reported positive effects of combining bales of straw or lucerne hay with other enrichment on reducing leg/foot problems in fast-growing broilers (Baxter, et al., 2018b; Vasdal, et al., 2019), and in slow-growing broilers, bales of straw have been found to increase activity levels (Bergmann, et al., 2017), whereas in fast-growing broilers some studies show an increased activity level, and others do not.

According to Riber and collaborators (Riber, et al., 2018), the provision of a **foraging substrate** such as sand that is preferred by broilers will stimulate its usage and can lead to increased foraging, thereby reducing inactivity. Offering different **dustbathing substrates** in smaller local quantities can stimulate dustbathing and foraging in preferred substrates (moss-peat and oat hulls) (Baxter, et al., 2018a). Recently, an oat hulls substrate has been considered a successful enrichment in terms of improving bird leg health (Baxter, et al., 2018b) and a moss-peat substrate has been considered successful in reducing fearfulness in fast-growing broilers (Baxter, et al., 2019). More research is needed on the use of dustbathing substrates as effective enrichment in slow-growing broilers.

Scattering all of the broilers feed in the bedding, rather than offering it in feeders stimulates activity of fast-growing broilers, but as a consequence reduces body weight (Jordan, et al., 2011). Scattering of additional food items, such as whole wheat, in the bedding, has not been found to be effective, as it did not influence time budgets, mortality, or other welfare parameters (Bizeray, et al., 2002a). Recently, the provision of live Black soldier fly larvae in the litter once daily has yielded positive effects on activity levels of both fast and slow-growing broilers (Blaauw, 2019). Therefore, the use of **food based enrichment**, such as larvae that are considered as a highly valued food by broilers, may be an effective form of enrichment, which deserves further research<sup>1</sup>.

The limited knowledge on providing **suspended strings** as foraging or pecking objects, shows that their use varied and their effect (if any) was limited (Riber, et al., 2018). Recently, other **pecking objects** such as plastic chains (Baxter and O'Connell, 2019), metal chains (De Jong and Gunnink, 2019) and pecking stones made of hard-pressed wheat bran (Bergmann, et al., 2017) were found to be well used by fast-growing broilers. However, scientific knowledge is unclear about effects of these objects on leg/foot health and on activity. In slow-growing broilers, pecking stones combined with other enrichment have been found to increase activity levels (Bergmann, et al., 2017), whereas in fast-growing broilers some studies show an increased activity level, and others do not. Moreover, an important aspect of non-food based enrichment aimed at stimulating foraging and pecking behaviour is that it should remain interesting to the birds throughout the entire rearing phase. This aspect should be considered in the design of future experiments for both fast and slow-growing broilers.

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<sup>1</sup> The Dutch SPA stresses the fact that there is insufficient knowledge on insect welfare when these are reared to be used as feed for chickens, and they therefore do currently not support this type of enrichment for broiler chickens.

**Table 7** A summary of broilers' use of the different kinds of point-source environmental enrichment reviewed in the present review and its effect on the prevalence of different welfare and production indicators measured. "Fast" and "slow" refer to growth rate. Adapted from Riber and collaborators (Riber, et al., 2018).

Type	Genotype	Use by the birds	Effect on								
			Activity level	Leg/foot problems	Heat stress	Fear level	Distribution in house	Disturbances	Growth	Breast blisters	Keel bone damages
Perches	Fast	Little	Unclear <sup>1</sup>	No effect	Reduced	No effect	Improved	Reduced	No effect	-	Increased
	Slow	Little	Increased	No effect	-	-	Improved	-	No effect	Increased	Increased
Platforms	Fast	Well used	Unclear <sup>1</sup>	Unclear <sup>2</sup>	-	Reduced	-	-	Unclear <sup>3</sup>	-	-
	Slow	Well used	Increased	No effect	-	-	-	-	No effect	-	-
Panels	Fast	Well used	Reduced	-	-	-	Improved	Reduced	No effect	-	-
	Slow	-	-	-	-	-	Improved	-	-	-	-
Barriers	Fast	Moderate	No effect <sup>4</sup>	Reduced	-	Unclear <sup>5</sup>	-	Reduced	No effect	-	-
Bales of straw, Lucerne or wood-shavings	Fast	Well used	Unclear <sup>1</sup>	Reduced	-	Unclear <sup>6</sup>	-	No effect	No effect	-	-
	Slow	Well used	Increased	-	-	-	-	-	-	-	-
Foraging substrates (supplement)	Fast	Well used	Unclear <sup>1</sup>	-	-	-	-	-	-	-	-
	Slow	-	Increased	No effect	-	-	-	-	No effect	-	-
Whole wheat (supplement) spread in bedding	Fast	-	No effect	Increased <sup>7</sup>	-	No effect	-	-	No effect	-	-
All feed spread in bedding	Fast	-	Increased	-	-	-	-	-	Reduced	-	-
Dustbathing substrates	Fast	Well used	Increased	Reduced	-	Reduced	-	No effect	Unclear <sup>3</sup>	-	-
	Slow	Little	Increased	No effect	-	-	-	-	No effect	-	-
Suspended strings	Fast	Little	Unclear <sup>1</sup>	Reduced	-	No effect	-	-	No effect	-	-
Pecking objects	Fast	Well used	Unclear <sup>1</sup>	Unclear <sup>2</sup>	-	No effect	-	No effect	No effect	-	-
	Slow	Unclear <sup>8</sup>	Increased	-	-	-	-	-	-	-	-
Novel objects	Fast	-	-	-	-	Reduced	-	-	-	-	-

<sup>1</sup>Some studies show an increased activity level, others do not; <sup>2</sup>Some studies show reduced leg/foot problems, others show no effect; <sup>3</sup>One study shows reduced growth and another one shows no effect; <sup>4</sup>Except stimulation of perching;

<sup>5</sup>Simple barriers increased susceptibility to the induction of TI compared to complex barriers or no barriers; <sup>6</sup>One study shows reduced fear level and another one shows no effect; <sup>7</sup>One study shows higher gait scores in comparison to a control group; <sup>8</sup>One study shows that pecking objects are well used and another one shows little use.

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### 3.1.2 More Complex Enriched Environments with Outdoor Access

There are no references available after the year 2017.

As already reviewed by Riber and collaborators (Riber, et al., 2018), studies on whether an outdoor area (or free range) offers an enriched environment for broilers are limited, but show that range use is stimulated by good cover on the range (preferably mature trees with good canopy cover, combined with a mixture of grass, lower vegetation, and nutritious plants) and beneficial weather conditions. Furthermore, range use increases with increasing bird age. Slow-growing breeds appear to benefit most from an outdoor area, as they show higher levels of use, activity, and travel further outside than fast-growing breeds. This benefit also manifests itself in better foot pad health and plumage condition compared to slow-growing birds that are kept indoors. Information on mortality and parasite risks for broilers is very limited.

### 3.1.3 More Complex Enriched Environments: The Higher Welfare Indoor Systems

There are no references available after the year 2017.

As already reviewed by Riber and collaborators (Riber, et al., 2018), the scientific knowledge on the effects of higher welfare indoor systems on broiler health and welfare is very limited, although these systems are increasingly used in practice. Briefly, these are relatively new systems with animal welfare standards positioned between conventional and organic broiler production systems (Riber, et al., 2018). Originally, the aim of these systems was to improve animal welfare with relatively moderate technical changes and, consequently, a moderate increase in production costs (Saatkamp, et al., 2019). They often use broiler breeds with a lower growth potential as compared to conventional systems or they use fast-growing breeds but have a lower maximum stocking density. Frequently, the environment in these production systems is richer in stimuli as compared to conventional systems, e.g., perches, substrate bales, pecking objects, and natural light (windows) are provided. They may also have a covered veranda, which provides a halfway house between the indoor and outdoor environment and provides scratching opportunities. Prevalence of welfare problems such as contact dermatitis, lameness, and heat stress is considered to be lower in these systems as compared to conventional systems (EFSA, 2010).

## 3.2 Practical inventory

### 3.2.1 Overview of the requirements for the use of enrichment in the different broiler production systems in the Netherlands and United Kingdom

Several United Kingdom and Dutch retailers now produce their own-label broilers in higher welfare indoor systems. For an overview of the Dutch production systems, refer for instance to Ellen and collaborators (Ellen, et al., 2012). Such systems offer enrichment, some in combination with natural light (windows) and often with a maximum stocking density in place. Some of these retailers (e.g., M&S in the UK) will still use a fast-growing breed in these higher welfare indoor systems, whereas all retailers in The Netherlands already use a slower-growing breed (Saatkamp, et al., 2019). Several large retailers, such as Albert Heijn and Jumbo that are market leaders in the Netherlands, are no longer supplying conventional fresh broiler meat and have replaced it with a new product from their own concept with (claimed) higher animal welfare (Saatkamp, et al., 2019). Differences exist between these new retail standard concepts developed in the United Kingdom and in the Netherlands, but common characteristics include:

- a more robust, slower growing breed, such as Hubbard JA757;
- a maximum average daily growth of 50 grams;
- indoor housing with more space, and at relatively lower stocking densities ( $\leq 38$  kg/m<sup>2</sup>);
- provision of enrichment, and an adapted light regime (sometimes including natural light).

In Table 1 (The Netherlands) and Table 2 (United Kingdom) of Appendix 1 the different retailer concepts are explained in more quantitative detail. For the purpose of the current report, the description of the different concepts was limited to the requirements for the provision of daylight, dark

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period, use of enrichment, breeds and stocking density. In most systems natural daylight should be provided in at least 3% of the useable area in the broiler house, the dark period should be of at least 6 continuous hours (8 hours is required in a few systems), and the requirements for the use of enrichment often include substrate bales, pecking objects, scattered grains, platforms or perches, but in most systems substrate bales are required. Specific information on breeds and stocking density is given in Appendix 1.

### 3.2.2 List of enrichments that are commonly applied into practice in the different broiler production systems in the Netherlands

Based on consultation of stakeholders, enrichments that are currently used in slow-growing broiler production systems in the Netherlands include: substrate bales, pecking stones, scattering of additional food items (such as whole wheat in the bedding), perches and platforms. In practice, there is not much variation in the use of enrichments. It seems that regularly one or two types of enrichment are used per farm, and mostly indoors. Substrate bales and additional food items in the bedding are types of enrichments that are often combined.

Regarding substrate bales, compact bales of Lucerne (20 kg, pressed, tied with 4 straps and sometimes provided inside a nylon feeding net) are currently used at circa 20-25 % of the farms that provide enrichment in the form of substrate bales. Some reasons for its limited use may include costs, because a bale of Lucerne is usually more expensive and is more quickly consumed by the chickens than a bale of straw. Old birds are able to consume large amounts of Lucerne, which may interfere with the intake of their regular diet. Moreover, Lucerne is retained in the gizzard for a long period of time, which may interfere with the period of fasting normally applied prior to slaughter. Therefore, in the majority of the farms (circa 75%) bales of straw are currently applied. Generally, long straw is chopped (4-5 cm), very tightly pressed and tied in small bales. The quantity provided corresponds to 1 bale per 1000 birds, but some (supermarket) concepts allow 1 bale per 2000 birds. The amount of kilos per bale depends also on the concept, but 20 kg is usually the minimum. The bales stay from the start until the end of the rearing period in the broiler house, and may be replaced during this period if, for instance, the top of a bale collapses after birds have been pecking on it. If a bale does not collapse by itself prior to slaughter, it is often broken down by the farmer so that it can spread in the bedding in the week before the slaughter. Alternatively to straw, chopped rapeseed straw or wood shavings (large curls) are also used as substrate for bales. Future research is needed to look at the availability, cost and sustainability of variable substrates.

Regarding pecking stones, mineral pecking stones of different hardness grades are commonly used for laying hens and are now being used for broiler chickens as well. The quantity provided varies according to the requirements from the different (supermarket) concepts.

Scattering of additional food items (such as whole wheat, at least 2 grams per bird per day) is also used in some broiler farms to increase foraging activity of the chicken. In practice, it does not seem to increase foraging activity of broiler chickens, and, if needed, it may be used to train the chickens to go inside the broiler house.

Regarding perches and platforms (without ramps), although required by some (supermarket) concepts (see Tables 1 and 2 in Appendix 1), their use by broiler farmers is also considered limited at the moment. When applied, particularly perches are not well used by regular fast-growing broiler chickens. Only the chickens that are lagging behind in growth seem to use the perches more frequently than the chicken with normal growth. In practice, bales of straw seem to be more frequently used as elevated resting places than perches by the broiler chickens. Moreover, chickens are often seen clustering around the bales. Thus, bales may have other functions than only perching.

Interestingly, hanging ribbons (long, fluttering in the air stream) throughout the broiler house before the chicks enter the house for the first time seem to reduce fearfulness. Some farmers use ribbons to habituate the chickens to the occurrence of movements coming from above in the broiler house, which may reduce the occurrence of fearfulness reactions. A radio is also sometimes used in the broiler house to avoid sudden panic reactions of the chickens.

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The majority of the farmers use moss-peat as litter (60-70%). Compressed straw pellets, wood shavings and chopped straw are also used.

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## 4 Results on Natural Light

### 4.1 Literature study

Commercial broiler production systems based on retailers initiatives to improve animal welfare above the minimum legal requirements have emerged in several European countries, such as the United Kingdom and the Netherlands (Saatkamp, et al., 2019; Vissers, et al., 2019). A common factor in the higher welfare indoor systems is the application of environmental enrichment, with or without natural light, or systems with a covered veranda or outdoor range, to stimulate locomotor activity and natural behaviours of the broiler chickens (De Jong and Gunnink, 2019). Requirements for the provision of natural day light (at least 3% of the useable area) and use of enrichment in higher welfare indoor systems used for broiler production in The Netherlands are given in Appendix 1.

Recently, it has been reported that in commercial houses with fast-growing broilers, provision of environmental enrichment (wood shavings bales, perches and metal chains) and natural light promoted bird activity more than providing environmental enrichment without natural light, or providing no enrichment (De Jong and Gunnink, 2019). Moreover, the combination of natural light and straw bales not only increased locomotor activity but also improved leg health in fast-growing broilers, as compared with flocks without natural light and straw bales and flocks with straw bales but without natural light (Bailie, et al., 2013). When perches and strings were combined with straw bales in houses with natural light, there was a negative effect on fast-growing broiler activity in areas away from the enrichments (Bailie and O'Connell, 2015), which may suggest that there were functional areas separating resting and active chickens. In another study, where the effect of an outdoor run and natural light on the welfare of fast-growing broilers was investigated, it was concluded that an outdoor run improved welfare of broilers more than natural light alone, but still more research is needed on the quality and intensity of lighting provided to broiler chickens (Ruis, et al., 2004). With regard to intensity, it has been suggested that specifically, the variation in light intensity is an important driver of the stimulating effects of natural light on broiler activity (Bailie, et al., 2013). This not only stimulates activity but is also suggested to better synchronise flock behaviour, which may lead to higher activity in the photoperiod and more uninterrupted resting in the dark period (Alvino, et al., 2009). Also, variation in light intensity across the broiler house may stimulate birds to use different areas around the house for different behaviours during the photoperiod, but this depends largely on the method of providing natural light. This means that the way in which windows are incorporated into broiler houses is also important, but this has not been investigated yet. All in all, there is still limited scientific knowledge about the effects of natural light (alone or in combination with enrichments) provision on behaviour and welfare of broilers, both of fast and slow-growing breeds. Though also relevant, scientific literature on health benefits of natural light (e.g., via endogenous synthesis of vitamin D) is not included in the current report, because it falls outside the scope of the study.

**Table 8** Natural light for broilers used in different studies.

Reference	Method	Quantity provided	Location	Dimensions (broiler house)	Genotype		Stocking density
					Slow-growing	Fast-growing	
Bailie, et al., 2013	Windows (double glazed, toughened glass)	46 windows*/house	At a height of 1.5m along the length of the two 'long' sides of the house	220 cm wide 360 cm high	-	Ross	17 birds/m <sup>2</sup> (but not exceeding 30 kg/m <sup>2</sup> )
Bailie and O'Connell, 2015	Windows (double glazed, toughened glass)	46 windows*/house	At a height of 1.5m along the length of the two 'long' sides of the house	220 cm wide 360 cm high	-	Ross 308	17 birds/m <sup>2</sup>
De Jong and Gunnink, 2019	Windows	42 windows** in the roof	Two rows of 21 windows (window area 1.25 m <sup>2</sup> )	1515 m <sup>2</sup> (approximately 18 x 85 m)	-	Ross 308	19.8 birds/m <sup>2</sup>

\* These windows were located at a height of 1.5 m along the length of the two 'long' sides of the house, and they were shuttered for the first 4 days of the rearing period and during the dark period of the artificial lighting regime.

\*\*Tulderhof, Eindhoven, The Netherlands.

## 4.2 Practical inventory

Based on consultation of stakeholders, provision of natural light is variable among the different slow-growing broiler production systems in the Netherlands. In organic broiler production systems, chickens are provided with an outdoor access (free range) or in the so-called '*Beter Leven*' 1 star system, broiler houses are provided with a covered outdoor area ("veranda") which gives direct access to natural light. In indoor systems, most broiler houses are equipped with windows in the roof slope enabling entrance of natural light in the house. Nevertheless, natural light can be provided in different ways. For example, through glass windows in the walls, polycarbonate black out roof windows, polycarbonate black out wall or roof ridges which can be (partially) closed using slats or screens. With slats, it is usually difficult to completely ban the light entry. If windows are in the walls there is usually less direct sunlight in the house and light entry will be more diffuse. In this way, it is also possible to provide a lot of variation in light intensity across the broiler house.

Normally, there should be a scheme for introducing natural light in the broiler house, because young chicks tend to avoid direct day light, and may smother on the areas of shadow along the sides of the broiler house walls. Therefore, in the first week of the rearing period windows are kept closed, and artificial lights are used (10 lux or higher). An alternative could be the provision of dark brooders, such as in the '*Windstreek*' system. After one week, the farmer starts with natural light provision (25-50% of capacity). If there is a lot of sun (high light intensity), the amount of natural light provided is kept low, and is gradually increased. If it is very sunny, farmers use the screens or slats to dim the light. When sensors are used, there is quite some variation according to the outside light conditions. Artificial lights are turned off during daytime, but may be temporarily turned on or used in addition to windows, if for instance weather conditions (clouds, rain, snow) hinder the entrance of day light in the house. With regard to the dark period, in practice, a period of 6 hours (retail concepts) or 8 hours ('*Beter leven*') of continuous darkness is required, but there is still a question on whether this period should be shorter or divided into more periods, to assure sufficient gut fill until the next light period.



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# 5 Results on Artificial Light

## 5.1 Literature study

### 5.1.1 Effects of light during incubation

Commercial broiler chicken eggs are often incubated in complete darkness, receiving light only intermittently when the incubator is opened, both to save electricity and because of concerns about potential negative effects on hatchability due to heat coming from the light source. Under natural conditions, however, chicken embryos would receive at least some light stimulation during development when the hen leaves the nest to feed or responds to distress calls from other chickens by rising to turn the eggs (Archer and Mench, 2014).

According to a series of peer-reviewed papers published by Archer and collaborators (e.g. Archer, 2017; Archer and Mench, 2013; Archer and Mench, 2014; Archer, et al., 2009), light stimulation during incubation can affect the behaviour and health of broiler chickens post-hatch. For example, light exposure during incubation has been shown to reduce fear and stress responsiveness post-hatch in broiler chickens, which can be beneficial for welfare (Archer and Mench, 2013; Archer and Mench, 2014). Moreover, providing light during incubation has no negative effect on production or health of broilers (Archer, et al., 2009). Recently, it has been shown that exposing broiler eggs to white light and red light that is a component of it are possibly the key spectrum to improving hatchability and lower fear and stress susceptibility, whereas green light is not as effective during incubation (Archer, 2017). These studies have been conducted with eggs from fast-growing broilers, and it would be interesting to investigate how light provision during incubation of eggs from slow-growing broilers may affect behaviour and welfare of these birds in the post-hatch rearing period.

### 5.1.2 Effects of ultraviolet wavelengths on chicken behaviour

There is increasing evidence that birds use ultraviolet (UV) signals in visually mediated behaviours, in both intraspecific signalling and foraging decisions (Maddocks, et al., 2001). In chickens, UVA wavelengths (as low as 360 nm) are visible and may facilitate interactions within the flock. UVB wavelengths (290–320 nm), although not visible to chickens, promote endogenous vitamin D synthesis, which could support the rapid skeletal development of fast-growing broiler chickens. Despite this, standard housing of broiler chickens is usually indoors and without exposure to UV or natural light throughout the whole rearing period. Although windows may be incorporated into broiler houses, glass does not typically transmit any UVB wavelengths of light and the transmission of UVA wavelengths is limited depending on the type of glass used. Consequently, light from windows may not be representative of sunlight and/or does not appear “natural” to a chicken (James, et al., 2018). Given the importance of UVA as a component of chicken visual feedback, the provision of these wavelengths could be considered an effective form of environmental enrichment. To date, not many studies have assessed the impacts of artificial lighting regimes including UV wavelengths on the behaviour and welfare of broiler chickens.

In laying hens, Ruis and collaborators (Ruis, et al., 2010) found several positive outcomes with UVA, such as increased preening and ground pecking, reduced fearfulness and reduced gentle feather pecking. Similarly, Kristensen and collaborators (Kristensen, et al., 2007) showed that six-week old broiler chickens performed more preening, object manipulation, foraging, and walking when reared in lighting conditions that included some UVA. Maddocks and collaborators (Maddocks, et al., 2001) found significantly lower baseline levels of corticosterone together with a non-significant trend for increased exploratory behaviours in layer chickens (Lohmann breed) that were provided with UVA. However, not all outcomes were positive: when laying hens were reared to 50 weeks of age, Ruis and collaborators (Ruis, et al., 2010) found that UVA increased incidence of severe feather pecking at certain ages. This was reduced in all lighting treatments after the introduction of substrate. Therefore,

Ruis and collaborators (Ruis, et al., 2010) proposed that UVA may have made the feathers of conspecifics look more appealing than in standard lighting, attracting more severe pecking in an environment lacking other stimuli.

UVA provision alone may not be a quick solution for welfare problems such as feather pecking, but it may improve the quality and the reliability of visual feedback as perceived by the chicken, potentially enhancing the appearance of both conspecifics and their environment. Particularly in coloured birds, it may increase visibility of plumage patterns. The studies mentioned above suggest that unless animals are housed in otherwise barren environments, UVA wavelengths can potentially facilitate more harmonious interactions within the flock and promote the expression of natural behaviours. Floor-housed broiler chickens are therefore a good candidate for investigating the impacts of UV wavelengths on behaviour and welfare, as they are typically provided with substrate (litter) and have a short rearing period before the onset of maturity, which means that feather pecking is not an issue (James, et al., 2018). To date, there was only one study assessing the effects of UV wavelengths on welfare indicators of fast-growing broilers (see Table 9), and there are no studies that have assessed the effects of UV wavelengths in combination with environmental enrichments on behaviour and welfare of fast and slow-growing broilers. Thus, this merits further research.

**Table 9** *Effects of UV wavelengths on different welfare indicators measured in fast-growing broilers reared under commercially representative conditions (N/A = information not available).*

Reference	UV treatment	Quantity provided	Welfare indicator			Genotype		Stocking density
			Feather condition	Fearfulness	Walking ability	Slow-growing	Fast-growing	
James, et al., 2018	UVA	18-hour photoperiod	Improved	Reduced	Improved	-	Ross	15
	UVA + UVB	18-hour photoperiod of UVA + 8-hour photoperiod of UVB	Worsened (trend)	Reduced (trend)	Improved		308	birds/m <sup>2</sup> (33 kg/m <sup>2</sup> )
	White LED control	18-hour photoperiod	Worsened	Increased	Worsened			

### 5.1.3 Light colour preferences of broiler chickens

Light colour is determined by different wavelengths in the spectrum. In broiler production white light (consisting of a combination of all the colours of the visible light spectrum) is often used. However, the composition of different wavelengths in white light can differ, resulting in apparent white light but with a different colour temperature. For instance, a 'warm' white light has a lower colour temperature (Kelvin) than 'cold' white light. The spectrum visible to chickens differs from humans. The eye of the chicken is more sensible to red and blue light (Niekerk, et al., 2015).

Usually, white fluorescent light is used in broiler chicken houses, but with the recent developments of LED lighting and consequently the switch from light bulbs towards LED in poultry housing, there has been a shift of attention to effects of the light spectrum (colour of the light) on broiler performance and welfare (e.g., Archer, 2018; Huth and Archer, 2015; Riber, 2015). With LED lighting, broiler chickens can be provided with a more complex and different light spectrum during the rearing period (Archer, 2018), which makes it possible to precisely adjust the light spectrum to the needs of the birds and potentially improve their welfare and performance. However, relatively little is known on the preference of broiler chickens for certain light colours or colour temperatures. It is therefore important to collect more information on the preference and behavioural responses of broiler chickens under varying light conditions, to develop light programs that promote broiler welfare.

There are indications that broiler chickens from three weeks of age onwards prefer cold white light (6065 K) rather than warmer white light (4100 K), measured by the time broiler chickens spent in the compartment with cold white light on days 16, 28 and 34 of the rearing period (Riber, 2015).

Moreover, resting behaviour occurred more often in cold white light than in warmer white light (Riber, 2015). In another study, Mendes and collaborators (Mendes, et al., 2013) found that broiler chickens from three weeks of age onwards had a higher feed intake in white compared to yellow LED light. Other research indicated that broilers housed under cold white light (5000 K) for the whole rearing period were less anxious and grew faster than broiler chickens housed under warm white light (2700 K) (Archer, 2018). Studies in humans show that preference for light temperature differ depending on the activity and time of the day (Philips, pers. comm.). However, this was only included to a very limited extent in the experiment of Riber (2015) and not included in the study of Archer (2018). Thus, it is not known yet whether or not light colour preference depends on the behaviour the chicken intends to perform. In addition, the preference of broiler chickens was only included in very few studies comparing two light colour temperatures (Mendes, et al., 2013; Riber, 2015).

**Table 10** Significant effects of colour lighting treatments in broiler chickens (N/A = information not available).

Reference	Treatment	Preference (if tested)	Effect on			Genotype		Stocking density
			Behaviour and welfare	Growth	Locomotion disorders	Slow-growing	Fast-growing	
Prayitno, et al., 1997a	Red, green, blue or white light (at 30 lux) from 7 to 28 days of age	Preferred green and blue to red and white (after 28 days)	Birds reared in red or white light were more active	No effect on growth and carcass composition	-	-	Ross	10 birds/m <sup>2</sup>
Prayitno, et al., 1997b	Red or blue light at three intensities from 1 to 35 days of age (exp. 1)	-	Activity increased with intensity in red but not blue light	-	-	-	Ross	7.5 birds/m <sup>2</sup>
Prayitno, Phillips and Stokes, 1997b	Bright red light in the early or late part of the rearing period (exp. 2)	-	Bright red light increased activity in the early part of the rearing	Bright red light increased growth in the early part of the rearing	Reduced by both early and late bright red light	-	Ross	N/A
Hesham, et al., 2018	Yellow, red, green and blue light (at 25 lux) until 12 weeks	-	- Increased eating in blue light - Increased preening, dustbathing and drinking in green light - Increased activity in red light, while, birds in blue light were calmest	No effect on growth	Numerically better health status of the foot and toe in blue light	Fayoumi (slow?)	-	N/A

Reference	Treatment	Preference (if tested)	Effect on			Genotype		Stocking density
			Behaviour and welfare	Growth	Locomotion disorders	Slow- growing	Fast- growing	
De Santana Eich, et al., 2016	Blue and red LED light until 42 days	-	Birds exposed to red LED light were more active than birds exposed to blue LED light	-	-	-	Cobb 500	12 birds/m2
Asih, et al., 2018	Intermittent blue lighting (IBL) and continuous blue lighting (CBL) until 28 days	-	- Increased duration and reduced frequency of feeding in CBL - Reduced corticosterone hormone concentration in CBL	Increased growth rate in CBL	-	Lohmann (slow?)	-	N/A
Khaliq, et al., 2018	Blue, green and red light in the evening hours until 6 weeks	-	- Increased occurrence of resting and comfort behaviours in blue and green light - Increased occurrence of aggressive behaviours in red light	-	-	N/A	N/A	N/A

As shown in table 10, little is known on the preference of broiler chickens for certain light colours. It seems that broilers show a preference towards red colour light (Senaratna, et al., 2018), which may be explained by the increased levels of activity found when birds are exposed to red light at different periods or throughout the entire rearing period. Nevertheless, colour preference tests have been hardly applied in experiments where lighting parameters were investigated in broilers. Next to that, setting of an optimum light intensity is difficult since dim intensities that favour growth reduce welfare (Senaratna, et al., 2018). Thus, studies where colour preferences are tested are needed, and when possible, also in combination with the testing of most effective intensity schedules that favours both performance and welfare in broiler chickens.

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## 6 Discussion and conclusions

The aim of the current report was to summarise the state-of-the art of knowledge with respect to effective environmental enrichment and lighting conditions for broiler chickens, as a starting point to define research questions specifically targeted to optimise housing conditions for slow-growing broiler chickens. This to better meet their behavioural needs and to optimise their welfare in commercial systems, while at the same time being practically applicable and economically efficient. Therefore, this literature study and practical inventory will form the basis for future trials regarding environmental enrichment and lighting conditions applied to slow-growing broiler production systems.

### 6.1 Environmental enrichment

Perching is considered part of the natural behaviour of chickens (Norrington, et al., 2016). Therefore, elevated resting places (such as perches and platforms) are generally accepted as an effective form of enrichment for broiler chickens, particularly for fast-growing broiler chickens due to, for instance, positive effects found on leg health (Riber, et al., 2018). Nevertheless, in practice, the use of elevated resting places is still considered to be limited in most slow-growing broiler production systems used in the Netherlands at the moment. Moreover, from the literature study, perch use seems to be quite variable whereas platforms are generally well used by slow-growing broiler chickens. It should be mentioned, though, that this information originates from a limited number of scientific publications reporting on the use of elevated resting places by slow-growing broiler chickens in recent years (see Table 1). Sometimes perch use in slow-growing breeds is low, but this might be due to perch design, including aspects such as material used (e.g. wood, metal), shape of perches (e.g. oval, round, rounded upper edges), how these are provided (e.g. A-frame, with/without access ramp), height and dimensions. Potentially, perches may improve leg health in slow-growing broiler chickens as well. But there might be a risk of increased prevalence of breast blisters and keel bone damage with perches (Nielsen, 2004). Further research on perch use, and its effect on behaviour and other welfare indicators in slow growing breeds is needed. Evaluation of optimal designs of perches should consider possible positive or detrimental effects on bird health.

In the particular case of platforms, recent studies have indicated that they may reduce fearfulness and thereby improve welfare of fast-growing broiler chickens (Baxter, et al., 2019; Tahamtani, et al., 2018). So far, the effect of platforms on fearfulness has not been tested in slow-growing breeds, but it is an important aspect for these breeds due to their higher activity level than fast growing breeds (Bokkers and Koene, 2003; Rothschild, et al., 2019) as compared to fast-growing breeds. Slow-growing broiler chickens may be very flighty and thereby damage each other, especially at catching. The provision of a more diverse environment, with for instance platforms combined with other type of enrichment (e.g. bales), may aid to improve leg health (Baxter, et al., 2018b; Vasdal, et al., 2019) and reduce smothering and injuries at catching by reducing fearfulness already during the production cycle.

Also, for both perches and platforms, it is interesting to test how large and/or how many of these elevated resting places should be provided in accordance to differences in group size and stocking densities encountered in the slow-growing broiler production systems used in the Netherlands. Is, for example, 2 meters of perches or 1 bale per 1000 birds, as applied in some production concepts, sufficient for during the whole production cycle?

With regard to other types of enrichment, from the literature study, the majority of the scientific publications (still mostly on fast-growing breeds) reported that bales of substrate (straw, lucerne hay or wood-shavings) are generally well used by both fast and slow-growing broiler chickens. Nevertheless, the number of publications reporting on the use of bales by slow-growing breeds was very limited (Bergmann, et al., 2017; De Jong and Van Wijhe-Kiezebrink, 2014). So, it merits further

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research in slow-growing breeds. In addition, bales are one of the few types of enrichment with multiple functions that have not been fully explored in broiler production systems yet. This is because bales are used not only for perching, but also for clustering around it (protection), and when partly open (thus, not wrapped in plastic), birds may use it also for explorative behaviour (pecking). To date, no studies have specifically documented the multiple uses of one enrichment, which could be considered as providing for multiple behavioural needs of broilers. Also for bales, it is interesting to test if there is an optimum number of enrichments per number of chickens that should be provided, and for the purpose of stimulating explorative behaviour, different levels of loosely pressed bales should be tested against the compact, tightly pressed bales that are currently used in most slow-growing broiler production systems used in the Netherlands at the moment. It is expected that loosely pressed bales will stimulate explorative behaviour more than tightly pressed bales, and possibly also at a younger age. So, loosely pressed bales could be provided to the birds already at the start of the production cycle, and different levels of looseness or firmness could be gradually introduced to the birds in accordance to their level of development and age.

Moreover, an important aspect of enrichment aimed at stimulating foraging and pecking behaviour is that it should remain interesting to the birds throughout the entire production cycle. This is difficult to maintain with non-food based pecking objects (e.g. strings, chains), but on the other hand, food-based enrichment, such as larvae, have been shown to stimulate foraging behaviour in slow-growing broilers in a sustained manner during the entire production cycle (Blaauw, 2019). This is a type of enrichment that is hardly used in slow-growing broiler production systems in the Netherlands, which also merits further research<sup>2</sup>.

## 6.2 Lighting conditions

Currently, little is known about the need for light in slow-growing broiler chickens and how this interacts with the environmental enrichment offered. More insight in the specific requirements of slow-growing broiler chickens with respect to light helps to provide housing conditions that better meet the needs of the birds, and thus contribute to broiler chickens' welfare. In consultation with stakeholders, it was decided to limit the literature study to three potential interesting areas of research: (1) effects of natural light provision and its variation across the broiler house; (2) effects of ultraviolet wavelengths on chicken behaviour; and (3) light colour preferences of broiler chickens.

From a few studies investigating the effect of natural light in combination with enrichment on chicken behaviour and welfare, there are indications that provision of natural light improves activity levels and leg health of fast-growing indoor-housed broiler chickens (De Jong and Gunnink, 2019; Bailie, et al., 2013). Moreover, dependent on weather conditions, natural light provides variation in light intensity across the broiler house, which may be relevant for promoting chicken welfare due to increased opportunity to perform different behaviours in different light environments. So, in farms where windows are provided along the side walls, resting behaviour occur more often in the darker areas (at lower light intensities) whereas active behaviours occur in the lighter areas (at higher light intensities), but it is up to the birds to choose under which circumstances they want to stay. In this way, provision of natural light to slow-growing breeds may be optimised, but this needs further research, where for instance, roof and side wall windows are compared.

Because natural light and enrichments may interact, the positioning of the enrichments in accordance to the variation in light intensity across the broiler house is also important. It would be interesting to test what would happen when birds are given the opportunity to choose between, for instance, a platform placed in a lighter area (likely stimulating activity) versus a platform placed in a darker area (likely stimulating resting). This may lead to the creation of different functional areas in the broiler house, and stimulate multiple uses of one single type of enrichment.

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<sup>2</sup> The Dutch SPA stresses the fact that there is insufficient knowledge on insect welfare when these are reared to be used as feed for chickens, and they therefore do currently not support this type of enrichment for broiler chickens.

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With regard to artificial light, light exposure during incubation may have positive effects on chicken welfare, by for instance, reducing fearfulness in later life (Archer and Mench, 2013; Archer and Mench, 2014). Moreover, light conditions at the hatchery or the breeder may already determine the colour preferences and affect behaviour of the offspring. But still, little is known on the preference of broiler chickens for certain light colours. So far, there are no studies that have been conducted in the Netherlands to test colour preferences in slow-growing breeds. Thus, studies on colour preferences in slow-growing broilers in relation to age and behaviour are directly needed. Also, in combination with variable colour temperature (cold and warm).

UV enrichment may have positive effects on behaviour, but studies on slow-growing breeds are not available at the moment. UVA wavelengths are visible to chickens and affects their perception of conspecifics (possibility of increasing visible plumage patterns in coloured birds) and their environment. So, it may be an effective and low-cost way to attract birds to enrichments, which might be more easy for some farmers to install.

In addition to light, provision of dark areas would be interesting, especially for young animals. So, studies on the provision of dark brooders to slow-growing breeds at the start of the production cycle are also encouraged.

## 6.3 Recommendations for future research

Regarding the current lack of knowledge on the behavioural requirements of slow-growing broiler chickens, various questions were raised, such as:

- What is the optimum perch design for slow-growing breeds and how does it affects (leg) health?
- What are the effects of certain types of enrichment, for instance platforms, on fearfulness?\*
- Is there an optimum number of enrichments per number of chickens that should be provided?
- What is the effect of single enrichment with multiple functions compared to different enrichments on behaviour and welfare?\*
- Do 'loosely pressed' bales meet the requirements for explorative behaviour (pecking) of the birds more than 'firmly pressed' bales?\*
- Is it possible to use larvae as an attractive type of enrichment which can stimulate foraging behaviour even more?
- How does variation in light intensities across the broiler house affect behaviour and welfare of the birds?\*
- Can we optimise light distribution across the broiler house by, for instance, providing light through windows along the side walls of the house instead of in the roof?\*
- Can we create different functional areas in the broiler house with different light intensities and/or colour temperatures in combination with enrichment?
- What are the colour preferences of slow-growing chickens in relation to age and behaviour?
- Can UV enrichment have positive effects on behaviour and welfare?
- Do young chicks avoid high intensity natural light? What are their preferences for natural light/intensity in relation to age? What is the effect of the provision of dark brooders to slow-growing breeds at the start of the production cycle?\*
- What are the effects of the interaction between lighting conditions and enrichment on chicken behaviour and welfare?

From this list, a limited number of research questions will be selected and used for the design of experiments on enrichment provision (year: 2020) and on light provision (year: 2021) in slow-growing broiler chickens. Priority will be given to the questions marked with an asterisk (some can be combined in one experiment). Different slow-growing breeds are used nowadays, and may differ with regard to their requirements for enrichment and light. Nevertheless, the main focus of the experiments will be on Hubbard breeds, which are considered representative of the Dutch slow-growing broiler market at the moment. Although it is not in the scope of the project, epigenetic effects may be taken into account in one of the experiments, but a final decision will be made on the course of the project.

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# Appendix 1

**Table 1** Overview of the requirements for the provision of daylight, dark period and use of enrichment in systems used for broiler production in The Netherlands (N/A = information not available). Source: Henk-Jan Schuurman (De Hoop Mengvoeders B.V., Zelhem, The Netherlands, personal communication); Ellen, et al. (2012); Saatkamp, et al. (2019), Dierenbescherming (2019).

Concept	Requirements			Maximum daily growth <sup>1</sup>	Stocking density
	Daylight in the stable	Dark period	Enrichment		
Regular (EU legislation)	No requirement	6 h of darkness, of which 4 h are continuous	No requirement	Not regulation	18-21 birds/m <sup>2</sup> (33, 39 or max. 42 kg/m <sup>2</sup> )
McDonald's (regular)	Provided through openings in the roof or in the facades (at least 3% of the useable area)	N/A	During the whole production cycle: 2 meters of perches per 1000 birds, and at least 1 pecking object per 1000 birds. From 8 days of age onwards: 1.5 bale of straw, hay or Lucerne, or plastic packaged wood-shavings (at least 10 kg) per 1000 birds	Not specified	N/A
Deen, Deka, Dirk, COOP, Hoogvliet, Jan Linders, MCD, Poiesz, Spar, Vomar (Groenland Kip)	At least 3% of the useable area	6 h of continuous darkness	Pecking stones (1 stone/250 m <sup>2</sup> ), elevated platforms (1m <sup>2</sup> /2500 birds)	50 gram	15-16 birds/m <sup>2</sup> (max. 38 kg/m <sup>2</sup> )
Boon's markt and MCD (Betere kip), Picnic and Boni (Comfort), Nettorama (Kiplekker)	At least 3% of the useable area	6 h of continuous darkness	From 15 days of age onwards: 1 bale of straw, Lucerne or hay per 500 birds, 2 grams of grain per bird scattered on the ground	50 gram	15 birds/m <sup>2</sup>

Concept	Requirements			Maximum daily growth <sup>1</sup>	Stocking density
	Daylight in the stable	Dark period	Enrichment		
Albert Heijn ( <i>nieuwe AH kip</i> )	No requirement	6 h of continuous darkness	1 straw bale/1000 birds	50 gram	max. 38 kg/m <sup>2</sup>
Plus ( <i>nieuwe Plus kip</i> )	At least 3% of the useable area	6 h of darkness	1 straw bale/1000 birds	50 gram	max. 38 kg/m <sup>2</sup>
LIDL	At least 3% of the useable area	6 h of continuous darkness	Distraction material, such as pecking objects (1 object per 150 m <sup>2</sup> of useable area), and elevated platforms (1 element per 150 m <sup>2</sup> of useable area)	50 gram	max. 38 kg/m <sup>2</sup>
Aldi	At least 3% of the useable area	6 h of continuous darkness	From 15 days of age onwards: 2 grams of grain per bird scattered on the ground, 1 straw bale per 1000 birds or 1 pecking stone per 200 m <sup>2</sup>	50 gram	15 birds/m <sup>2</sup> (max. 34 kg/m <sup>2</sup> )
Jumbo ( <i>nieuwe standaard kip</i> )	At least 3% of the useable area	8 h of continuous darkness	From 15 days of age onwards: daily scattering of at least 2 grams of grain per bird, 1 whole bale (at least 20 kg) of straw, hay, Lucerne or maize per 1000 birds	45 gram	13.5 birds/m <sup>2</sup> (max. 30 kg/m <sup>2</sup> )
Beter Leven keurmerk (1 star)	At least 3% of the useable area	At least 8 h of continuous darkness	From 8 days of age onwards: 1 bale (15-20 kg) of straw, hay or Lucerne per 1000 birds. From 15 days of age onwards: daily scattering of at least 2	45 gram	12 birds/m <sup>2</sup> (max. 25 kg/m <sup>2</sup> )

Concept	Requirements			Maximum daily growth <sup>1</sup>	Stocking density
	Daylight in the stable	Dark period	Enrichment		
			grams of grain (or feed) per bird, done manually by the farmer		
Organic	Provided	At least 8 h of continuous darkness	No requirement	Not specified	10 birds/m <sup>2</sup> (max. 21 kg/m <sup>2</sup> )

<sup>1</sup> Dependent on the supermarket concept, different slow growing breeds may be used such as Hubbard JA (957, 757, 257), Ranger classic, Rowan Ranger, Ranger Gold, Rambler Ranger, Cobb Sasso 150, Sasso SA 451 N. Hubbard breeds have a share of approximately 75% of the total Dutch slow-growing broiler market (Van Boekholt, pers. comm.). Slow-growing broiler chickens are defined as broiler chickens produced by slow-growing female parent stock that are crossed with a regular or slow-growing male. These broiler breeds are either accredited by the Dutch SPA with the 'Beter Leven' quality label (maximum average daily growth of 45 grams) or fall within the standards of the original 'Kip van Morgen' concept (maximum average daily growth of 50 grams) (Ellen, et al., 2012; Saatkamp, et al., 2019).

**Table 2** Overview of the requirements for the provision of daylight, dark period and use of enrichment in systems used for broiler production in the United Kingdom. Source: Annie Rayner (FAI Farms, Oxford, UK), pers. comm.

Concept	Retailer	Requirements			Genotype		Stocking density
		Daylight in the stable	Dark period	Enrichment	Slow-growing	Fast-growing	
UK Standard Red Tractor <sup>a</sup> - Ingredients/added value/Entry level	TESCO, Sainbury's, ASDA, Morrisons, Co-op, ALDI, LIDL, Waitrose, M&S	Evenly spaced and minimum 3% (recommended) floor area in windows <sup>a</sup>	Minimum 6 hours, with 1 period of 4 hours uninterrupted every 24 hours	1 bale, 2m of perches or 0.3m <sup>2</sup> platform or 1 pecking object per 1000 birds	Not specified	Permitted	38 kg/m <sup>2</sup>
UK Higher Welfare Retailer Schemes	Waitrose and M&S	Evenly spaced and minimum 3% floor area in windows	Minimum 6 hours, with 1 period of 4 hours uninterrupted every 24 hours	Provision of bales	Not specified	Cobb (M&S)	30kg/m <sup>2</sup>
RSPCA Assured Indoor	Sainsbury's	Minimum 3% floor area in windows	6-12 hours continuous	1.5 bales, a 2m perch and 1 pecking object per 1000 birds	JA57, JA787, JA987, Ranger Classic, Ranger Gold, Rambler Ranger	Not permitted	30 kg/m <sup>2</sup>
Free range	TESCO, Sainsbury's, ASDA, Co-op, Morrisons, ALDI, LIDL, Waitrose, M&S	Natural light outdoors and through pop holes	Minimum 6 hours continuous	1 bale and 1 pecking object per 1000 birds, 2m of perches and 0.3m <sup>2</sup> platform per 100 birds	Permitted	Reared until 56 days	27.5kg/m <sup>2</sup>
Organic	TESCO, Sainsbury's, ASDA, Co-op, Morrisons, M&S, Waitrose	Plentiful natural light	Minimum 8 hours continuous	Perches, straw/hay/alfalfa bales, vegetables and other vegetation, with at least 2 enrichments per 500 chickens.	Slower growing recommended but not mandatory	Reared until 70 days	21kg/m <sup>2</sup> (30kg/m <sup>2</sup> mobile housing)

<sup>a</sup>From 1<sup>st</sup> October 2020.





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