The antioxidant role of carotenoids across different housing systems

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Consumers in developing countries are increasingly demanding more transparency on egg production (animal welfare) and safety. These two drivers are very important and have changed the face of the European industry over the last 20 years. For instance, Switzerland banned conventional cages in 1992 and about 20 years later conventional cages were no longer an option for EU egg producers. However, in China, Japan, Russia, Ukraine, the Americas and the rest of the world, conventional cages remain the norm.

In 2015, the International Egg Commission (IEC) published a comprehensive review of the different housing systems available for layers, providing an evaluation of the several options from different perspectives.

The report demonstrated that there is no such thing as the ideal housing system for every farmer, region and country. Evaluation criteria vary and factors such as welfare, productivity, sustainability and health and safety have to be taken into consideration.

What is also clear, according to the IEC, is that only when food security is no longer a problem, can animal welfare gain importance.

The objective of this article is to discuss briefly the economic, environmental and health aspects of different egg producing systems and to relate this information to a recent paper by Paneheleoux and Hamelin (2015) analysing the production traits to feed carotenoid content in relation to housing.

Animal health and welfare

Back in 2005, EFSA published an opinion on animal health and welfare related to different housing systems (Table 1). At the time, it was clear that even as hens gained freedom of movement in non-cage systems, a different kind of welfare problem was arising in the form of cannibalism and parasitic diseases. Feather pecking is common in non-cage systems but can be solved by beak trimming, although animal rights activists are now putting this practice under the spotlight.

In order to further clarify welfare status, a multi-institute paper was published in 2011 considering conventional cages, furnished cages, non-cage and outdoor systems.

Table 1. Welfare dangers in different laying hen housing systems (Adapted from EFSA, 2005).

Conventional cages	Low bone strength and fractures sustained during depopulation. Inability to perform priority behaviours including nesting, perching, foraging and dust bathing.
Small furnished cages	Feather pecking and cannibalism in flocks with no beak trimmed birds. Depending on layout, some high priority behaviours (for example foraging and dust bathing) cannot be performed or are limited.
Large furnished cages	No data available on relevant issues like bone fractures, feather pecking and cannibalism.
Non-cage systems	Leg fractures sustained during lay. Feather pecking and cannibalism in flocks with no beak trimmed birds. If an outdoor run is provided for birds in non-cage systems, there is a high risk of parasitic diseases.

Some of the highlights included:

- Environments in which hens are exposed to litter and soil, such as non-cage and outdoor systems, provide a greater opportunity for disease and parasites.
- The more complex the environment, the more difficult it is to clean, with increased difficulty for disease and pest control.
- Conventional cages can limit movement and lead to osteoporosis, but non-cage systems expose hens to an increased incidence of bone fractures.
- More space allows hens to perform a greater behavioural repertoire, although cannibalism can occur in larger groups.

As a conclusion, Lay et al., stated, "Although environmental complexity increases behavioural opportunities, it also introduces difficulties in terms of disease and pest control." Even in the same housing system, housing materials (such as wood or plastic) can make a difference.

In 2015, Jasper et al. found that wire mesh flooring is better than plastic flooring for preventing feather pecking and reducing red mite infestation at the same time. Wire mesh flooring allows a better overall hygiene standard.

For this reason, welfare is not a definitive factor to judge the best housing system, even when stress levels are considered. Stress has been traditionally measured through corticosterone, epinephrine and norepinephrine levels.

An enormous amount of work has been carried out in this field and still no clear winners have been declared. It has not been demonstrated that outdoor systems reduce stress for laying hens.

Production costs

The general belief is that a conventional cage system is the least expensive way to produce eggs. In order to verify this information,

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Table 2. Egg production and performance as affected by housing system (Adapted from Panheleoux and Hamelin, 2015).

	Feed intake (g/day)	Egg weight (g)	Laying rate (%)	Livability (%)
Organic (4)	119.1±1.16[b]	58.8±0.54[c]	89.5±2.15	99±0.70
Enriched cages (9)	119±0.63[a]	57.5±0.32[b]	93.9±0.59	99.7±0.17
Free-range (8)	120.6±0.93[b]	55.1±0.43[a]	91.7±0.50	99.4±0.40
	<0.05	<0.01	NS	<0.05

Hen age (weeks)	Housing system	Carotenoids in yolk (ppm)	Average (ppm)
22	Organic	31.4±1.82^{a}	
	Cage	23.4±2.46^{b}	25.1±1.64^{a}
	Free-range	22.0±2.46^{b}	
26	Organic	26.0±1.6^{a}	
	Cage	21.3±1.83^{ab}	20.2±1.40^{b}
	Free-range	16.5±2.09^{b}	
30	Organic	26.3±5.41	
	Cage	20.6±1.36	19.6±1.39^{b}
	Free-range	16.3±1.10	
		<0.05	<0.05

Table 3. Carotenoids egg content according to hen age and housing system (Adapted from Panheleoux and Hamelin, 2015).

	Intake	Egg weight	Laying rate	Hen weight	Livability
Tbars	-	-0.29*	-	-	-
Carotenoids in yolk	-	0.46**	0.39**	0.33*	-

Table 4. Pearson's correlation between performance and egg markers (*P<0.05, **P<0.01) .

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Matthews and Sumner (2015) reviewed the production cost of three different systems (conventional cage, cage-free aviary and enriched colony) situated in the same location, under the same management, feeding and accounting procedures.

Cage-free aviary and enriched cage system eggs were respectively 36 and 13% more expensive to produce than those produced with conventional cages.

Labour, energy, pullet cost, mortality and other factors were responsible for the higher production costs, which reflected in a higher selling price for the eggs.

Sustainability

Although the discussion on how to assess sustainability is still open, it is important to recognise that it can not be limited to social (including welfare) or environmental factors.

Indicators of sustainability have to address the components of people, planet and profit. In other words, any system has to be positive for the people (healthy, nutritious, safe), and friendly for the environment as well as profitable in order to sustain the operation in the long term.

Discussing these three aspects, van Asselt (2015) published a paper where the above three factors were analysed for egg production systems in the Netherlands; namely enriched cage, barn, free-range and organic.

Using equal weight for the indicators, enriched cage production was more sustainable from the environmental point of view, whereas free-range eggs received the best scores from a social dimension. From an economic standpoint, enriched cage and organic egg production had the highest sustainability score. The conventional cage was not included, but over the years, this system has proved to be more economical and less damaging to the environment.

Pelletier and colleagues published a paper in 2014 where the environmental footprint of the egg industry in the USA was compared between systems in 1960 and 2010. In this period, there was a reduction of 71% in greenhouse and eutrophying emissions, in conventional cage systems.

Antioxidant status

Egg quality and antioxidant status is a specific area that has not been fully addressed and where more information is needed. A recently published French field trial suggests that the housing system, along with the feed's carotenoids and antioxidant status are closely linked. Different production systems were studied: nine layer flocks in furnished cages, four flocks managed according to organic rules, and eight farms managing their birds in a free-range system.

Performance criteria considered with each flock included daily per capita feed intake, eggs laid per bird, average egg weight and viability.

Recording for each flock was from laying start at week 18 through to week 30. Ten eggs were sampled from each farm at weeks 22, 26 and 30. These eggs were assessed for beta-carotene equivalent (BCE) content via iCheck photometer and for antioxidant status through a Tbar test with results expressed as mM malondialdehyde(MDA)/kg yolk.

Once again, the investigation reported here reflects the reality of commercial production through considering a mix of bird types. Nine flocks comprised IsaBrown birds, seven Lohmann, two NovaBrown and one flock featured Bovan birds.

The aim was to concentrate on brown egg production enterprises, this eggshell colour being popular in the French market. Because a range of reactions between the different bird types and housing/management could be expected, the results (average daily consumption (CMJ), egg weight, hen liveweight and laying percentage) are expressed as a percentage according to the genetic standard. For instance CMJ 100 = CMJ/genetic standard x 100.S.

As expected, performance (Table 2) was affected by the housing/management system: feed intake was higher and more variable with free-range. Free-range averaged 120.55g/day, organic 119.13g/d and furnished cages 118.96g/d. The recordings show average egg weight is highest with organic (58.7g) and lowest with free-range (55.05g).

There was no statistical difference in laying rate and hen live weight. Cumulative viability of free-range and organic layers is not only lower but also more variable than with hens in furnished cages (p<0.05).

Influence of housing

The Tbar antioxidant status of the egg yolks was found to decrease significantly (p<0.05) as hens aged (Table 3), averaging 513 at week 22, 494 at week 26 and, at week 30, 393. Results show no significant effect from type of housing/management in this respect. Table 4 shows that the carotenoid content in egg yolks decreased as hens aged (p<0.05), with differences according to housing/management system. For instance, at week 30 the organic figure averages 26.34ppm, the cage result 20.56ppm and free-range 16.29.

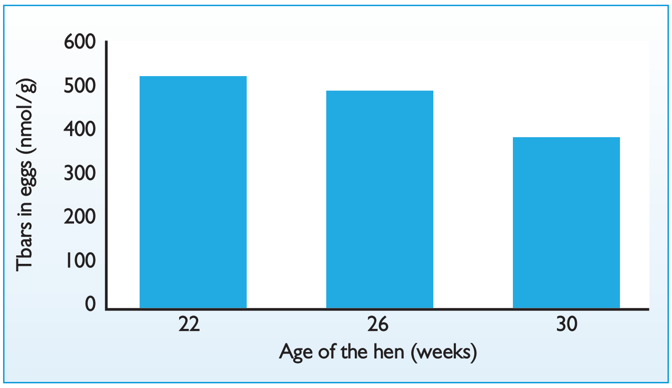
Also highlighted by this investigation is a significant negative correlation between Tbars and egg weight.

Thus, when the egg weight increased, their oxidative status also increased, as shown by a decrease in Tbars readings. However, correlations between yolk carotenoid content and laying performance, average egg weight and hen liveweight are seen to be significantly positive (Fig. 1). This report from a comparatively extensive field study of young layer performance in 19 different egg production farms effectively emphasises the importance of the carotenoid content (as beta carotene equivalent) and its relationship with egg laying performance and liveweight gain with birds at the start of the production cycle.

In the results displayed, carotenoid content in yolk correlated positively with performance criteria.

Correlations between performance and egg markers were detected. While the overall performance of the layers in the field research was demonstrated to depend on the housing system involved, a decrease in oxidative status was recorded when hens aged, regardless of the housing system. Carotenoid content (as beta-carotene equivalent) also decreased with ageing hens and was different according to the housing/management system involved. A high carotenoid content was related to a higher antioxidant status and a heavier egg.

Fig. 1. Correlation between yolk oxidation and hen age (Panheleoux and Hamelin, 2015).



Conclusion

- The challenges for a hen vary according to the housing systems. There are no clear recommendation according to welfare, or stress.
- The egg production and cost is housing-dependent.
- The carotenoid content of eggs is well correlated with laying percentage and egg weight across different production systems. ■

References are available from the author on request