Titulo: Comparative study of the quality and of the nutritional profile of eggs from commercial laying hens and free-ranges hens: Bibliography review.

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Índex:

1. Abstract:

Eggs constitutes a very valuable food due to its content of essential nutrients such as proteins, lipoproteins, vitamins, lipids, minerals…etc. Although for some time its consumption was decrease as it was believed to be a risk factor for cardiovascular diseases, later studies found that this was not true. During the 20th century there was a boom in the use of commercial laying hens that cause a decrease in the use of native hens. Many native hens currently are at the brink of extinction, and this constitutes a problem for local farmers and for the biodiversity of hens. As the use of native hens nowadays is increasing because they are better adapted to extensive systems and the population concern of animal welfare is also increasing, studies that compare the quality of native hens to commercial hens are more common. Across the different studies selected in this bibliography review we can see that native hens are a good and viable alternative to the commercial hens. We can also see that as well as breeds have an effect in the quality of the eggs, the diet and the housing and management of the hens also have an effect on the quality of the eggs. Breed and diet also affects the nutritional profiles of the eggs. Overall, it seems that according to the bibliography consulted, commercial hens better quality as they have higher egg weight and eggshell strength, but the native hens had better nutritional profiles as they have higher fat and protein content and better lipid composition for people with some chronic diseases like diabetes. Native hens also seem to have higher content of Ca, vitamin E and some carotenoids. In order to obtain good quality eggs from native hens under free-range systems it is important to have a good diet and management.

2. Introduction:

The egg is a very valuable food from a nutritional point of view that has a prominent role in the Mediterranean Diet. During the 1970s and 1980s, egg consumption was drastically reduced due to the belief that its cholesterol content was a risk factor for cardiovascular disease, but in the last decade of the last century, it began to recover its role in the diet, when it was verified that this preponderance as a risk factor was not true (Sastre, A., *et al.*, 2003).

In 2017, the world production of eggs exceeded 1416 trillion tons of eggs, equivalent to 80 million metric tons, 30% higher than production in 2000 (http://fenixservices.fao.org/faostat/static/documents/EI/EI_e.pdf (accessed on 24 February

2019)). In the European Union, the production of food in alternative production systems is on the rise; in 2017, free range and organic egg production accounted for 20% of the total production of eggs (https://ec.europa.eu/agriculture/eggs_es (accessed on 24 February 2019)). Currently, almost all of the consumed eggs are produced by commercial hybrid lines, which are characterized by high productive performance and a good feed conversion index (Mottet *et al*., 2017 and Tallentire *et al*., 2018) However, the exploitation of these highly productive lines causes a decrease in the genetic variability of the species and has negative effects on the development of sustainable practices based on local breeds (González Ariza *et al*., 2019).

Eggs are considered a complete food for the human diet due to their large amounts of essential nutrients such as proteins, lipoproteins (ovalbumin, ovotransferrin, HDL and LDL), a wide variety of minerals (potassium, phosphorus, calcium, iron, magnesium), vitamins (A, D, E, K, B6, B9, B12, riboflavin), lipids (Monounsaturated fatty acids, Polyunsaturated fatty acids, carotenoids, choline and phospholipids) and other bioactive compounds (Kuang *et al.*, 2018).

In this bibliography review we are going to see the differences of quality in the eggs of the commercial laying hens and the free-range native hens and their differences of nutritional profiles. The use of native hens in free-range systems is increasing nowadays due to the also increasing concern of the population of animal welfare. To aim in the objective of find better production methods for native hens many authors had made studies that compare the quality of eggs between these 2 groups. The objective of this bibliography review is to compare the quality and nutritional profile of commercial and free-range laying hens eggs and what factors influence them.

But before we see these studies it is important to known what the commercial laying hens and the free-range native hens are.

2.1 Commercial laying hens:

2.1.1 Characteristics of the breeds

Commercial laying hens are a type of hens that are selected for their high production performance (Lordelo *et al*.,2020). In Spain they were introduced during the late 20th century (González Ariza *et al*., 2019, González Ariza *et al*., 2021). The commercial hens are genetically designed to have a high productive performance and a good feed conversion index (González Ariza *et al*., 2019). Their introduction brought about an increase in the productive

capacity of egg and meal but at the cause of local genotypes and their genetic diversity (González Ariza *et al.*, 2021a). Some examples of commercial laying hens are Isa brown, Leghorn and Hy-Line Brown. Historically during the first half of the 20th century the most used laying strains from the beginning were of the White Leghorn breed for white eggs and New Hampshire and Plymouth Rock Barrada for brown eggs. In Spain the Castilian Black Breed was also used for white eggs and Prat Leonada for tinted eggs. During the second half of the 20th century the White Leghorn breed was consolidated as the only white egg producer and since 1980, different brown egg crosses have been consolidated using the New Hampshire breed as the paternal line and a synthetic population that provides the silver gene and the dominant white as the maternal line, or the Rhode Island Red crossed with the Rhode Island White, also with sexing genetic via silver gene. Poultry genetics currently depends on a few multinational companies (Campo, 2009).

Image 1. White Leghorn breed

Image 2. New Hampshire breed

2.1.2 Feed

The standard laying feed is usually has: 2.750 kcal/kg, 17% Brute Protein 3,8% Ca (FEDNA, 2018)

It is important to know that the needs of the laying chicks in regard to feed vary according to their age, as we will see now. FEDNA (Spanish Foundation for the Development of Animal Nutrition) established nutritional recommendations for blonde layers in cages.

Table 1 nutritional recommendations for blonde layers in cages. FEDNA

		Pre-peak (16 to 25 weeks of age)	Start of laying (26 to 50 weeks of age)	End of laying (>50 weeks of age)	shell problems
EMAn	Kcal/Kg	2670	2730	2700	2680
Added fat	%	>3.2	>3.0	>1.5	≤1.0
Linoleic acid	%	1.35	1.35	>1.20	>1.1 <1.3
Crude fiber min.-max.	%	>4.0 – 5.3	3.6 – 5.6	3.5 – 5.8	3.4 – 6.0
Crude protein, min.	%	17.0	16.6	15.8	15.0

EMAn refers to Apparent metabolizable energy zero nitrogen retention.

2.1.3 Housing and management

The commercial laying hens are often breed in intensive systems. In these industrial. production, the concept of breed is little considered, since production is based on many lineages, crosses and hybrids, with the aim to achieve high production parameters (number of eggs and/or egg weight). However, the improvement of these productive parameters sometimes has a detrimental effect on egg quality, being the genotype of a great importance in the nutritional profile of eggs as said by (Franco *et al*., 2020) and supported by other authors like (Gonzalez Ariza *et al*., 20121a). Conventional cage systems were developed in the 1930s and used in traditional egg production since the 1950s. These systems have been around a long time and their sole purpose was to maximize profit and productivity with more hens being housed in a small area and therefore having a higher egg production. Before EU Directive 1999/74/EC in Spain the cages normative were established in EU directive 86/113/EEC and the concept of enriched cage wasn't mentioned in this Directive. The Enriched cages were first developed in Germany during the 1980s and have since been improved. These cages are different from conventional cages which provide more space for each hen (750 cm2 space per hen) and are equipped with a perch, nest, scratching area, and nail shortener (Yilmaz *et al*., 2016).

EU Directive 1999/74/EC establishes the requirements that conventional cage and enriched cage must meet.

For example, conventional cage must have at least 550 cm2 of cage surface per hen, a feeder that can be used without restrictions should be provided and its length must be at least 10 cm multiplied by the number of hens in the cage, the cages must have a height of at least 40 cm over 65% of the cage surface and no less than 35 cm at any point. The cage must also have suitable nail shortener devices. In the previous EU directive 86/113/EEC the only differences were cage surface per hen was 450 cm2, and the cages didn't have to have nail shortener devices.

For enriched cage as it was said in the study of (Yilmaz *et al*., 2016) should have at least 750 cm2 of cage surface per hen, 600 cm2 of them of usable surface, with the understanding that the height of the cage apart from the one existing above the usable surface must be at least 20 cm at any point and that the total surface of the cage may not be less than 2000 cm2. They also should have a nest, a litter a litter that allows pecking and digging, suitable perches offering at least 15 cm space per hen, feeder that can be used without restrictions with a length of at least 12 cm multiplied by the number of hens in the cage, appropriate drinker, nail shortener.

Image 3 Conventional cage system

Image 4 Enriched cage system

2.1.4 Nutritional profiles of eggs.

Nutritional profile of the eggs refers to the percentage of moisture, fat, protein, ash of the eggs or the eggs components yolk and white, fatty acids composition, vitamins, carotenoids, minerals, toxic metals among others. They are rather internal properties of the eggs that cannot be seen with the naked eye and can be affected by different factors as we will see later in this work.

Eggs from commercial hens usually had lower crude proteins and crude fats compared to free-range (Franco *et al*., 2020, Gonzalez Ariza *et al*., 2021a). They also seem to have higher moisture levels in the white and higher ash content in the yolk (González Ariza *et al*., 2021a, Sirri *et al*.,2018). In terms of fatty acids composition, commercial hen's eggs had higher concentrations of Monounsaturated fatty acids (MUFAs), but lower concentrations of Polyunsaturated fatty acids (PUFAs) and Saturated fatty acids (SFAs), although it varies and some commercial hen's eggs could have higher concentrations of some PUFAs or lower concentrations of some MUFAs as we would see in this review, they also have lower concentrations of omega 3 (González Ariza *et al*., 2021a, Rizzi and Marangon., 2012). Later, these differences will be described in more detail according to the reviewed bibliography.

2.2 Free-range hens:

2.2.1 Types of farms: free-range, ecological….

Alternative to the intensive systems arose due to the growing interest in animal welfare. Following public concern about conventional cage systems for laying hens they were banned in the EU in 2012 and only enriched cages systems or non-cage systems, such as aviaries, barn, free range, and organic systems are allowed in the European Union (EU Directive 1999/74/EC) (Yilmaz *et al*., 2016). Aviaries are multi-tier systems that consist of a littered ground floor and a metal structure with up to four tiers (row-type aviaries). They vary in design, although all systems typically have feeders, drinkers, and perches located on one or more tiers (Heerkens *et al*., 2015). Hen's that lay eggs classified as barn eggs are not kept caged but are kept in large sheds with litter on the floors. They can flap their wings and partake in dust baths. Free range eggs are laid by chickens that roam freely outside and are not caged. Organic chickens are usually free range, but do not receive hormones or antibiotics and are fed an organically derived diet (Rogers, 2009). In Spain free-range systems are non-caged hens with access to the outside (FEDNA, 2018).

2.2.2 Characteristics of the breeds

The breeds usually use in the free-range systems are native hens characterized by their rusticity, resistance, and adaptability to the environment (Lordelo *et al*., 2020). The use of native hens could be an interesting alternative to production systems, such as extensive or

free-range systems, in places where climatic fluctuations across season are extreme (Gonzalez Ariza *et al*., 2022).

In Spain there is the Utrerana hens, they are part of the Mediterranean truck consisting of lighter individuals, with white earlobes and of a white-shelled egg-laying morphotype (González Ariza *et al*., 2021). The Utrerana has four varieties of plumage color: White, Franciscan, Black, and Partridge. The other laying hen genotype that traditionally configured production under backyard and extensive systems in Spain is the Sureña that has these varieties of plumage color: White, Franciscan, Black, Partridge, Blue, and Splash. As it was already said these breeds are more adapted to the climate in Andalusia that is characterized by maximum temperatures rising among 40ºC in summer, as reported by the Spanish State Meteorological Agency (AEMET). The Sureña breed has greater potential as a dual-purpose breed, while morphometric traits of the Utrerana breed may be indicative of higher profitability in egg-producing farms (González Ariza *et al*., 2021). They are different native hens in each country that are adapted to the environment of their country.

Other examples are Portuguese breeds of chickens (Branca, Amarela, Pedres Portuguesa, and Preta Lusitanica) (Lordelo *et al*., 2020).

The Mos hens that are the autochthonous breed with the highest census in Spain and is known for its great rusticity, allowing it to adapt to the extensive production systems like other native hens (Franco *et al*., 2020).

In Italy there is the Romagnola hens characterized for being a rustic animal, extremely variable for plumage, tarsus, and skin color (Sirri *et al*., 2018).

Image 5 Romagnola hen breed

In the Canary Islands there is a hen known as the Canarian hen that has this varieties of color: La Jabada are dark colored birds with white striped markings on feathers which look like scales. Las Doradas that have gold and white striped markings on feathers which look like scales. Las negras canarias are black coloured bird with greenish blue iridescent tones. Las

Rubilanas that have yellow colour from pale to a goldish tone bodies and black colored base of the neck and tail tips. And finally, Las Aperdizadas o Coloradas which have these characteristics: the head and neck are a gold colour with a black tip, the back shoulders and wings are a uniform brown, the belly is a salmon red. The abdomen and the thighs are ash grey, and the tail is black (Ball, 2019).

Image 6 La Jabada hen breed

Image 7 La dorada hen breed

We can keep going to the different countries and we could find more autochthonous breeds each with its own characteristic with constitutes a great biodiversity. Native hens provide a pool of potential useful genetic resources for commercial strains (Lordelo *et al*., 2020).

2.2.3 Feed

Free-range hens are usually and mainly fed farm feeds such as whole cereal grains or a mixture of ground cereals and potatoes (Krawczyk and Gornowicz, 2010). These farm feeds are usually used in rural-type poultry farming like with the Mos breed in which the diet usually include wheat, corn, pea, or triticale (Franco *et al*., 2020). The rest of the nutrients are usually obtained by these layers by eating various grasses, herbs and also small creatures like larvae or grubs and with that assimilate valuable natural nutrients that influence some egg quality traits (Krawczyk and Gornowicz, 2010).

In floor systems like aviaries or free-range FEDNA also had

Table 2 nutritional recommendations for blonde layers in floors, FEDNA

		Pre-peak (16 to 25 weeks of age)	Start of laying (26 to 50 weeks of age)	End of laying (>50 weeks of age)	shell problems
EMAn	Kcal/Kg	>2700	>2730	2700	2680
Added fat	%	2.0	2.5	<2.0	≤1.0
Linoleic acid	%	1.39	1.30	>1.20	>1.0 <1.2
Crude fiber min.-max.	%	4.1 – 5.6	4.2 – 6.0	4.3 – 6.2	4.3 – 6.2
Crude protein, min.	%	16.8	16.4	15.5	14.9

2.2.4 Housing and management

The free-range system, known as a backyard system, was dominantly used before the cage was invented until the 1920s. These systems are floor systems, which provide access to the outdoors and provide more space for behavioral freedom, optimum comfort, and welfare to the hens (Yilmaz *et al.*, 2016). These extensive systems surge because of the welfare concern associated with farming of poultry under intensive conditions and the other reason is consumer concern of animal welfare (Yilmaz *et al.*, 2016). Free range systems are part of the non-caged alternative systems their use with native hens protect the biodiversity of the hens as well as animal welfare. In this group also are the barn, aviaries or organic systems that we already talked about in the section of type of farms.

2.2.5 Nutritional profile of eggs

Eggs from free-range hens usually had higher crude proteins and crude fats compared to commercials hens (Franco *et al.*, 2020; Gonzalez Ariza *et al.*, 2021a). They also seem to have lower moisture levels in the white and lower ash content in the yolk (González Ariza *et al.*, 2021a; Sirri *et al.*,2018). In terms of fatty acids composition, free-range hen's eggs had lower concentrations of MUFAs, but higher concentrations of PUFAs and SFAs, although it varies and some free-range hen's eggs could have lower concentrations of some PUFAs or higher concentrations of some MUFAs as we would see in this review, they also have higher concentrations of n3 (González Ariza *et al.*, 2021a; Rizzi and Marangon., 2012).

2.3 Influence on egg quality and nutritional characteristics of eggs in commercial and free-range native breeds:

Now that we have summarized what are the commercial laying and free-range hens it's time to talk about the different factors that affects the quality and nutritional profile of the hens' eggs. We could say that the quality and nutritional profile of the eggs have been influenced mainly by these three factors: Breed, feed and housing and management. And by reviewing different studies and their results of different parameters of egg quality (weight, eggshell strength…etc.) and the nutritional profile (Chemical composition, fatty acids composition…etc.) we could see that indeed, these factors have a clear influence on the quality and nutritional profile of the egg. In this work, we focused on the difference between native hens and commercial hens. The different articles and works use in this bibliography review focused on that because the use of native hens normally is kept on free range-systems, and commercial hens are reared on cage. So, the term of free-range chickens in this work refers more to the native hens normally use in free-range systems. The factors that have a effects on the quality or the nutritional profile of the eggs are.

2.3.1 Breed

Studies on the different hen breeds and their effects on eggs have been done for a long time. Back in the 60s, there were numerous reports that contain reviews of research dealing with the influence of breeding and/or age of laying hens on egg size and the relative proportions of shell, yolk, and albumen in eggs (Cunningham *et al*, 1960; Marion *et al*., 1964, 1965; Kline *et al*., 1965). Generally, these reports support the conclusion that egg size can be controlled by breed, in addition to being influenced by age of the laying hen. Proportions of egg components appear to be modifiable by selective breeding but are greatly influenced by layer age (Marion *et al*., 1966).

As we have already said native hens are more adapted to the environment and in the study of (Gonzalez Ariza *et al*., 2022) the native hens had a sharper seasonality, influenced by its genotype-season interaction, hence temperature and photoperiod may greatly influence the egg production.

Studies that compare the native hens of their countries are increasing in order to protect them for example (Lordelo *et al*., 2020) found that Branca, Amarela, Pedres Portuguesa, and Preta

Lusitanica, which are 4 native Portuguese hens, match or supersede the quality of a commercial product in many characteristics, especially the Pedres and Preta. In markets where eggs from local breeds are available, consumers are purchasing a high-quality product while aiding in the expansion of local genetic resources and investing in local farmers and maintaining biodiversity.

(Godoy, 2020) made the first study that compare egg quality between the Canarian free-range hen and the commercial hen (Leghorn and Isa Brown), both being fed the same nutritional base. The study was made using the data of a previous study about the egg quality of the Canarian free-range hen (Ball, 2019). The results of this study were important to the "Asociación `La Campera´ for the recovery of La Gallina Campera Canaria", which works in order to protecting and safeguarding the Canarian free-range hen breed.

In terms of egg quality, it is well known that the commercial laying hens are made to have a better feed conversion because these breeds are selected for efficiency.

Among egg quality-related traits, we would see in different studies (Gonzalez Ariza *et al*., 2019; Sirri et al., 2018; Franco *et al*., 2020, Godoy, 2020; Lordelo *et al*., 2020) how breed influence parameters like Egg weight, eggshell weight, eggshell strength, egg shape, egg yolk color, egg Haugh unit.

Related to the nutritional profiles of the eggs, there are different results, although there were significant differences in all parameters measured (moisture, fat, protein, and ash), between the two genotypes by (Franco *et al*., 2020; González Ariza *et al*., 2021a; Rosa *et al*., 2020), (Sirri *et al*., 2018) found no significant difference in terms of moisture, total fat, and crude protein between Romagnola hens and commercial laying hens. Regarding Fatty acids (FAs) different authors found different results. Some found difference in the eggs of the breeds analyzed and others not.

Eggs are also known to be an important source of carotenoids. Carotenoids are organic pigments and there are differences in this compound concentration between different hen breeds as we could see in the study of (Bunea *et al*., 2017).

In the case of mineral composition of eggs. (González Ariza *et al*., 2021a) assess the ability of these hen breeds to metabolize heavy metals and to accumulate them in different parts of the egg (yolk, white and eggshell).

We will see the results of these studies more in depth later in the analysis and discussion.

2.3.2 Feed

The diet of the hens may be the most important factor in the quality and nutritional profile of eggs. As was previously said in this work. Commercial hens usually are feed with complete diets with high protein and mineral components (Krawczyk and Gornowicz, 2010). And free-range hens are feed with farm feeds such as whole cereal grains or a mixture of ground cereals and vegetables with the addition of eating various grasses, herbs and also small creatures like larvae or grubs of the environment (Krawczyk and Gornowicz, 2010).

As we have already said nutritional necessity varies depending on the age of the hen, as well as depending on the production system (FEDNA, 2018)

Mos breeds are, as we have already established, the autochthonous breed with the highest census in Spain. They are feed with farm diets as many free-range hens, that usually contains wheat, corn, pea, or triticale as said in the study of (Franco *et al*., 2020). This study feed Mos and Isa brown three different diets in order to see their effects on quality and also nutritional profile. Other studies of the influence of diets in the quality and nutritional profile were (Iskender *et al*., 2017) and (Kowalska *et al*., 2021)

In the analysis and discussion, we will see their results.

Regarding FAs profile references have addressed the fact that cholesterol deposition in the egg yolk can be affected by nutrition. Diet contents of MUFA, SFA and PUFA directly affects the MUFA/SFA ratio found in hen eggs (Bunea *et al*., 2017).

2.3.3 Housing and managent

The housing systems are also a factor in egg production. In a study made by (Yilmaz *et al*., 2016), 3 different housing systems were compared, conventional cage (CC), enriched cage (EC), and free range (FR).

In the analysis and discussion, we will see what they found.

3. Material and methods

To carry out this bibliographic review, I have relied on the use of academic google to search for different articles that deal with the subject in question. In this case, the issue in question is the comparison of the quality and of the nutritional profile of eggs of commercial laying hens and eggs free-ranges native chickens. This subject is a question that has been studied by many authors and therefore the number of articles dealing with it is very large. To reduce the number of articles that I had to include in this bibliographic review, I have focused on using articles that deal with breeds of hens used in Spain. Although I also use some studies of hens outside Spain. In the search for these articles I have used, certain keywords among which were “native-hen” and “free-range hen”. Once I was finding interesting articles on the subject, I filed them in different folders depending on whether they talked about the nutritional profile of the eggs like proteins, carbohydrates fatty acid composition, or general quality characteristics such as eggshell weight, texture, or color... etc. of the eggs. Throughout the review an order has been followed. First talking about more general issues regarding factors that affect the quality of eggs and then going into the nutritional profile. The latter especially focused on the lipid profile of the egg, which is one of the most important factors of selecting eggs for many people. In the introduction I first described briefly the commercial and free-range hens systems and then I introduce different studies and finally in the analysis and discussion I will summarized their results and compare them with each other and with other authors and what role have their findings in the quality of the eggs as a product.

4. Analysis and discussion

The importance of the egg in the diet of many places of the world is undeniable. Eggs are good source of many nutrients like proteins, amino acids, vitamins, fats…etc. and many eggs components like the yolk constitute an essential ingredient for the preparation of a large variety of food emulsions, such as mayonnaises, salad dressings and creams. Over time, studies that tell us extensively and regularly about its many beneficial properties have been published in numerous media, including some that deny some uncertain beliefs about them. With the arrival of commercial chicken lines, egg laying productivity has increased but with the negative consequence that native breeds have been losing their importance, this has caused the genetic variety to be lost. The products of commercial laying hens are very homogeneous in its characteristics, and although that can be considered in certain aspects a good thing, the truth is that more and more consumers are demanding new healthy products. Not only the necessity of the market for the development of new products, but also the growing concern of the consumers in respect of animal welfare have made an increase in studies that compare the quality of native hens with commercial hens in order to establish better methods of exploitation of the native hens and so point towards the conservation of animal genetic resources. In different studies present in this work, we can see that the quality of eggs and their nutritional profiles are influence by different parameters. Two of the most important ones seem to be Diet and Breeds as they affect both the quality parameters and the nutritional profile. Housing and management seem to affect the quality parameters but, in the bibliography, consulted in this work, its influence on the nutritional profile was not found. Not all parameters have the same effect in the quality of eggs. In the different studies, different values were found, and some authors agreed with the results of the articles in this work and others did not, as we will see below.

4.1 Breed: Effects of breeds in the characteristics of eggs

4.1.1 Quality of eggs

Table 3. Effects of breeds in the quality of eggs

(Franco *et al.*, 2020)	(Gonzalez Ariza *et al.*, 2019)	(Sirri *et al.*, 2018)	(Lordelo *et al.*,2020)	(Godoy, 2020)
There were no differences in egg weight between commercial and free-range hens	Eggs weight were heavier in the commercial hens	Also found heavier eggs in commercial hens when compared to free-range native hens		The Canarian free-range hens had higher weight compared to the commercial hens.
There was no difference in eggshell strength between commercial and free-range	Eggshell weight was higher in commercial hens and therefore they had higher eggshell breaking strenght	Eggshell strength was higher in the commercial hens cause of the higher eggshell weight	The Amarela, a portuguese native hen, had less percentage of shell and more prevalence of shell cracks than commercial hens	Similar eggshell thickness was found between Canarian free-range hens and commercial hens
	Leghorn eggs had significantly longer length and width. Partridge variety of Utrerana reached the same length of Leghorn eggs	Native hen's eggs had lower shape index.	Amarela, Pedres Portuguesa, and Preta Lusitanica, which are 4 native Portuguese hens had a better egg shape than commercial hybrid laying hens.	Canarian free-range hens show a longer maximum length than the eggs of the commercial hen.
	Commercial hens had higher Haugh units	There were no differences in Haugh units between commercial and native hens		Commercial hens had higher values of Haugh units than the Canarian free-range hens.
	Yolk darkness was higher in Utrerana eggs than in Leghorn ones.	Native free-range hen had higher values of redness and yellowness of yolk.	Luminosity of cooked yolk was higher in commercial hens and yellowness of cooked yolk was higher in native hens	

As was said in (Gonzalez Ariza *et al*., 2019) the higher egg weight is because of the higher concentration of water in the egg white, Utrerana hens had higher yolk weight so egg weight in commercial hens is produced at a lower energetic cost as its synthesis is energetically more efficient, on a weight for weight basis, than deposition of yolk. But as consumers begin to demand and consider egg energy as a quality criterion, egg selection for a higher percentage of yolk will be necessary. (Sirri *et al*., 2018) also found higher egg weight in commercial hens but (Franco *et al*., 2020) found no differences and (Godoy, 2020) found higher egg weight in native hens. Breeds influence the egg weight but as mentioned by (Marion *et al*., 1966) age are the primary factor that influence this parameter.

As we can see in the case of eggshell weight and therefore eggshell breaking strength, commercial hens generally have better quality because having a better eggshell strength means that the eggshell cracks are less likely to occur and therefore there is less economic losses (Franco *et al*.,2020). Eggshell weight is usually related to eggshell thickness and therefore eggshell breaking strength. Eggs that have thinner shells show lower crushing strength, so they have more cracks in their shells and so have lower quality (Krawczyk and Gornowicz, 2010). Although we can see that there are some exceptions like (Godoy, 2020) that found higher weight and similar thickness of eggshell in the native hens.

In regard to egg shape, this parameter is related to the egg weight and in the study of (Gonzalez Ariza *et al*., 2019) and (Sirri *et al*., 2018) egg shape is better in the commercial hens and egg weight is higher also in these two studies.

Regarding yolk colors the studies it seems that it depends on the breeds that we are talking about. In the studies of (Gonzalez Ariza *et al*., 2019; Sirri *et al*., 2018; Lordelo *et al*.,2020) yolk color was higher in native hens. Consumers tends to think that darker yoks are a sign of healthier eggs (Gonzalez Ariza *et al*., 2019), but the differences on color could be due to the breed and to the diet as we see later on.

Haugh units are also an important parameter to determine the quality of eggs that relates the height of the albumen to the weight of the egg. In the studies of (Gonzalez Ariza *et al*., 2019) and (Godoy, 2020) commercial hens had higher values of this parameter.

As for their nutritional profiles:

4.1.2 Chemical composition

Table 4. Effects of breeds in chemical composition

(Franco *et al*.,2020)	(Gonzalez Ariza *et al*., 20121a).	(Sirri *et al*., 2018)	(Rosa *et al*., 2020)
Isa Brown hens had a higher moisture content, while those eggs from Mos hens showed higher lipid, protein and ash contents	Higher concentration of crude proteins and crude fats and lower concentration of ash in the Utrerana hens' yolk in comparison to Leghorn hens. Higher crude protein, crude fat, and raw ashes in the white of Utrerana that Leghorn hens. Carbohydrate content was higher for Leghorn yolks and lower in Leghorn whites.	No significant difference was observed in terms of moisture, total fat, and crude protein between Romagnola hens and commercial laying hens. But in terms of ash content, they were lower in the romagnola egg yolk.	The Siciliana egg yolk showed higher values of moisture and ash compared to commercial hens and the albumen showed higher moisture and lower energy and protein content.

As we can see the results varies but it can be seen that the native varieties are not inferior to the commercial lines, in fact (Franco *et al*., 2020 and Gonzalez Ariza *et al*., 2021a) coincide in the higher protein and fat content in their corresponding native hens. A higher crude proteins content in the eggs prevents disruption and decrease interfacial tension because of the oil-water interface film forming function of egg yolk proteins and its act as a mechanical barrier due to its viscoelastic properties (Anton *et al*., 2003). The lower raw ash content in Utrerana egg yolks support those previously reported by other authors, since lower ash contents have been reported for native breed yolks when compared to those from selected lines of laying hens, like in (Sirri *et al*., 2018) that compared egg quality traits of Romagnola chicken breed to commercial hybrids. But some studies like (Rosa *et al*., 2020) found different results as they found that the native hen had higher ash content compared to commercial hens. The fact that carbohydrate content was higher for Leghorn yolks and lower in Leghorn whites (Carbohydrate content was computed from total sum of moisture, fat, protein, ash percentage and subtracted from 100) compare to the Utrerana in the study of (González Ariza *et al*., 2021a) is very positive, given Utrerana eggs may present more

desirable features for high-protein rich diets, especially indicated for people suffering certain dietary-linked or endocrinological conditions such as diabetes as found by (Fuller *et al.*, 2015).

4.1.3 FAs composition

Table 5. Effects of breeds in the Fatty acid composition

(Franco *et al.*,2020)	(Sirri *et al.*, 2018)	(Bunea *et al.*, 2017)	(González Ariza *et al.*, 2021a)
-Bird genotype did not alter the MUFAs (monounsaturated fatty acids) or PUFAs (polyunsaturated fatty acids) of eggs, although the content of oleic acid (C18:1n9c) the main Fatty acid of both genotypes was higher in Mos eggs than in Isa Brown ones. -The highest values of SFAs (Saturated fatty acids) were observed for Mos genotype - A lower numerical value of n6/n3 ratio was observed in Mos breed although it was not significant.	-Romagnola yolks had a higher MUFAs and lower PUFAs concentration compared to commercial hens - Higher proportion of SFAs compared to the commercial lines -lower PUFA n-6 content and PUFA n-6/n-3 ratio. -Romagnola had higher levels of cholesterol	-Small differences in the fatty acid profiles, and only in some minor fatty acids. -Black and Speckled Italian hen eggs have a more favorable n-6/n-3 ratio	- Generally, the native hen's yolk had higher concentrations of total PUFAs. Utrerana hen yolks showed a significantly higher content in some monounsaturated fatty acid, specific, oleic acid (C18:1 n9) and 7-hexadecenoic acid (C16:1 n9). - Higher concentrations of SFA in Utrerana egg yolks in comparison to Leghorn

Eggs have been historically atributed for causing coronary disease due to their high cholesterol content, which in turn even promoted its consumption to decrease, as mentioned at the beginning of this work. But clinical trials like the one made by (Djoussé and Gaziano, 2008) have demonstrated the absence of any link between egg intake and an increase in serum cholesterol concentrations in humans. In the study of (Sirri *et al.*, 2018) it was theorized that the higher cholesterol content found in yolk of Romagnola eggs could be explained by the far

lower deposition rate of these unselected hens compared to the commercial hybrids ones. Commercial hybrid hens are the result of a strong selective breeding process, which has tremendously increased their productive performance in comparison to unselected lines such as local breeds. It is widely recognized that an inverse relationship exists between yolk cholesterol content and egg deposition rate (Elkin, 2006).

There is a possible difference in lipid metabolism among Italian chicken breeds as the results of (Sirri *et al*., 2018) were different in other studies about Italian native hens like (Rizzi and Marangon., 2012). The latter findings being more like the ones of (González Ariza *et al*., 2021a) suggesting a similarity between fatty acid metabolism in the Utrerana hens and others unselected Mediterranean avian breeds.

In general, the fatty acid composition obtained for both breeds in the study of (González Ariza *et al*., 2021a) were in concordance with the levels reported by (Bunea *et al*., 2017). Essential fatty acids are precursors of hormone-like eicosanoids (such as prostaglandins, leukotrienes, and thromboxanes) that are involved in the regulation of heart pressure, heart rate, vascular dilation, blood clotting, immune response, lipolysis, and the central nervous system in humans (Kostogrys *et al*., 2017). This means that black variety of Utrerana and Leghorn breed eggs could be intended for special human diets with higher requirements of essential fatty acids, as for example in people with skin or cardiovascular diseases, and the higher total PUFA found in Utrerana hens could be effective to prevent and treat chronic diseases, frequently occurring in Europe (Jandacek, 2017).

The higher content in some monounsaturated fatty acid in Utrerana hen is also a positive trait as (Qian *et al*., 2016) reported MUFA, followed by PUFA are the most desirable fatty acids to be present in human diet. The reason for this, is that this type of fats produces a better mitochondrial functioning, which in turn prevents cardiovascular disease by lowering cholesterol and helps avoid complications associated with diabetes such as kidney damage. (Fuller *et al*., 2015) found that high egg consumption did not have an adverse effect on the lipid profile of people with Type 2 Diabetes (T2D) in the context of increased MUFA and PUFA consumption so high-egg diet can be included safely as part of the dietary management of T2D, and it may provide greater satiety. (Kuang *et al*., 2018) observed that current studies have tended to show that the consumption of eggs is not a risk factor of cardiovascular disease (CVD) in healthy people. However, they also said that people who are at high risk of CVD such as those with diabetes or hypertension need to have caution with dietary cholesterol

intake, especially egg intake. Previously cited studies (González Ariza *et al*., 2021a; Bunea *et al*., 2017) showed that this was not true as the fatty acid composition of eggs they found were good for the heart.

A very high ratio of n-6 to n-3 PUFAs in the diet may promote the pathogenesis of cancer as well as inflammatory and autoimmune diseases and so lower PUFA n-6/n-3 ratio is recommended for a healthy profile of egg lipids being associated to the reduction of the risk of several chronic diseases afflicting the western society. So Romagnola, Mos and Black and Speckled Italian hen eggs are healthier as the results founded by Sirri *et al*., 2018; Franco *et al*.,2020 and Bunea *et al*., 2017 showed.

4.1.4 Carotenoids:

(Bunea *et al*., 2017) found that Lutein and zeaxanthin were the predominant carotenoids in egg yolks and β-cryptoxanthin and β-carotene were also present at very low concentrations. The highest lutein concentration was found in Red Italian (67.02 µg/g) and the lowest in Gold Araucana (10.27 µg/g). The highest zeaxanthin concentration was found in the Silver Laced Wyandotte breed (29.36 µg/g) and the lowest in Gold Araucana (5.08 µg/g). The highest β-cryptoxanthin content (2.23 µg/g) was found in the Speckled Italian breed, and the lowest (0.62 µg/g) was found in the Partridge Brahma. And the highest β-carotene concentration was found in Silver Laced Wyandotte (0.76 µg/g) and the lowest in Red Italian (0.22 µg/g).

Lutein and zeaxanthin have been found to protect egg-yolk lecithin liposomal membranes against oxidative damage and lutein and β-carotene have been found to put down peroxy radicals and to display antioxidant properties against oxidative damage in vitro in the study of (Sujak *et al*., 1999). In the study Red Italian had the higher lutein and tocopherol (the major form of yolk vitamin E in domestic birds (Speake *et al*., 1999)) and therefore there could be a positive correlation between these 2 parameters.

4.1.5 Mineral composition:

As found by (González Ariza *et al*., 2021a) eggshells of Utrerana hens had higher concentration of Ca than the leghorn. Some authors like (Ahmed *et al*., 2005) linked the eggshell strength with calcification-related genes. The CALB1 gene is associated with Ca transport, both in uterus and intestine. Hence, the CALB1 expression affects the strength of eggshell and could be variable between breeds or even varieties. González Ariza *et al*., 2021a also found than Utrerana had also higher concentration of Mg. Mg is known to inhibit calcite formation, supporting the precipitation of aragonite (another crystal form of calcium

carbonate) (Rodriguez-Navarro *et al*., 2002). Therefore, it can be assumed that the Ca-Mg exchange equilibrium depends closely on changes in the concentration of either of these elements.

Metals could be harmful to humans, especially when they are taken in excessive quantities. Such toxic substances are eliminated by birds using several methods, one of them being deposition in eggs and feathers as stated by (Burger, 1994). Although eggs are a notable essential elements source, the consumption of eggs does not necessarily mean a considerable contribution of toxic metals (Vehad *et al*., 2019). European legislation does not establish any limits on toxic metals in hen's eggs (Rubio *et al*., 2017). (Vehad *et al*., 2019) compared their results of content of heavy metals with other studies from different countries and saw that the results vary between each location so an environment factor is also present.

4.2 Feed:

In order to obtain eggs with good quality parameters under harsh free-range conditions, layers should be fed complete diets or farm feeds enriched with at least high-protein and mineral components (Krawczyk and Gornowicz, 2010). It is clear that the ingredients of the commercial diets seem to have a better influence on the quality parameters of weight and yolk color. In this way (Franco *et al*., 2020) found that feed affect egg quality parameters as the results using tree different diets, the ingredients of the CF diet were corn, soybean flour, wheat, calcium carbonate, wheat bran, palm oil, beet molasses, glycerin, dicalcium phosphate and sodium chloride. The other two diets were a mixture of corn/pea/triticale (CPT), with corn (40%), triticale (40%) and pea (20%), and a mixture of corn/wheat (CW) with corn (66%) and wheat (34%). He found that CF diets had better egg weight, as well as the thickness of its shell. This fact can be attributed to deficiencies in calcium and phosphorus in the diets based on CPT and CW. CF diets also had the highest egg yolk color score and this could be because the percentage of corn rich in carotenoids is higher in the CF diet and the fact that there is a lack of carotenoids in triticale and wheat, so CPT and CW diets had low carotenoids.

In this study the ingredients of the commercial diets seem to have a better influence on the quality parameters of weight and yolk color.

Also, regarding the nutritional profiles Franco *et al*., 2020 found that:

- Eggs of laying hens fed with CF had a higher amount of protein; meanwhile, eggs of hens fed with CW and CPT had a higher fat content. So, both diets have its benefits and deficits.

-CW feed had higher MUFAs content, but CF had higher PUFAs content. SFAs content was not modified by the different feeds.

- There was a variation in the n6/n3 ratio between diets, being the highest for CF (15.56%) and the lowest for CPT and CW (12.45%), in the study it was stated that different authors tried to change the diet in order to see the effects in the Fatty acids composition as we can see in the table below.

Table 6. Effect of feed in the fatty acid composition

(Winkler *et al*., 2017)	(Krawczyk *et al*., 2015)	(Secci *et al*., 2018)	(Kostogrys *et al*., 2017)
Observed an increase in linoleic acid (C18:2n6c) levels and n6 fatty acids when they replace corn and wheat in the diet of Hy-Line Brown hens with oats hulls	Reported that the addition of yellow lupine to the bird diet resulted in a decrease of oleic acid (C18:1n9c) and consequently the MUFA content; but on the other hand, the PUFA content increased, as well as n6 content and the n6/n3 ratio.	Replaced soybean by black soldier fly meal in the Lohmann Brown Classic hen feed and observed changes in all fatty acids, except oleic acid (C18:1n9c). Moreover, MUFA and PUFA were higher in the diet based on soybean, while SFA was higher in the diet based on insects	Found that feeding hens the diets with pomegranate seed oil results in increased level of punicic acid (CLnA) as well as Conjugated linoleic acid (CLA) in egg yolks' lipids.

This shows the importance of the diet in the fatty acids composition and why the development of nutritional strategies to modify fat composition in animal products has been extensively investigated.

(Iskender *et al*., 2017) studied how dietary supplementation of flavonoids, the major secondary metabolites that plant synthesize, affect egg quality and nutritional profile. The flavonoids were hesperidin, naringin and quercetin. The dietary treatment didn't alter the quality of eggs, but it did alter the nutritional profile as hesperidin and quercetin decreased total cholesterol concentration and increased egg yolk total protein content. This eggs with lower cholesterol and higher protein yolk levels could be attractive for some consumers that will choose these eggs for some aspects of human nutrition and health.

(Kowalska *et al*., 2021) compare two feeds. One based on soybean meal and the other based on seeds from narrow-leaved lupin (Boruta). In terms of quality, egg shape, HU and yolk color were higher in the second diet. In terms of nutritional profile there were differences in the lipid profile between both diets. The content of MUFAs and omega 9 FA were lower in the second diet, but the PUFAs, omega 3 and 6, PUFA/SFA ratio, omega 9/6, omega 9/3 were higher. The study concluded that legume seeds diets could substitute soybean meal in small farms that cannot produce soybean meal.

4.3 Housing systems and management:

In the study of Yizmaz *et al*., 2016 it was found that Free range hens had higher dirtier egg ratio but laid larger eggs with higher weight that those from enriched cage and conventional cage, because free range had a higher final weight. But in a previous study (Krawczyk and Gornowicz, 2010) free range hens were characterized by lower total eggs weight, lower weight of different morphological components, and thinner shells that showed lower crushing strength. Therefore, although free range can have some benefits like additional space for optimum comfort and welfare, it is important to know that in order to have good quality eggs in layers raise in harsh free-range conditions the hens should be fed complete diets or farm feeds enriched with at least high-protein and mineral components.

The study of (Gonzalez Ariza *et al*., 2019) reported higher pH values in the Utrerana hens' eggs white. The white pH has been suggested to increase as CO2 decreases inside the egg. Factors related to this loss of CO2 such as the time of storage and high temperatures have been suggested to promote such a pH increase and a subsequent decrease in white viscosity and flavor, hence directly depreciating egg quality. So is important to not commit these errors if we want to have good quality free range native hens' eggs.

5. Conclusions

The analysis of different studies about egg quality and nutritional profile whether they are native hen or commercial hen, free range or raised in cages or other systems, led to these conclusions

1. Eggs are food with great quality, and it is very beneficial to incorporate them into the diet in a balanced way. The egg is a valuable source of many nutrients such as as proteins, lipoproteins (ovalbumin, ovotransferrin, HDL and LDL), a wide variety of minerals (potassium, phosphorus, calcium, iron, magnesium), vitamins (A, D, E, K, B6, B9, B12, riboflavin), lipids (Monounsaturated fatty acids, Polyunsaturated fatty acids, carotenoids, choline and phospholipids) and other bioactive compounds.

2. Native hens are better suit in extensive systems like free-range, system that keep the concern about animal welfare, protect the biodiversity and help local farmers.

3. Breeds affect the quality of eggs, commercial hens in general have a more efficient energy synthesis and lay larger eggs, has higher productive performance, has better eggshell and HU, but native hens have better yolk color.

4. Breed also affects the nutritional profiles. In general, native hens has better eggs for people that have some metabolic condition like diabetes or some cardiovascular disease because of their nutritional profile.

5. Eggs of native hens constitutes a good alternative to commercial hens' eggs if the prices and production costs are viable or profitable.

6. Diet affects both the quality and the nutritional profile of eggs. The use of native hens requires and adequate diet in order to have eggs that are comparable to the commercial lines. Little differences in diets could affect the quality but above all it affects the nutritional profile, especially lipid profile.

7. Housing systems and management also affects the quality of eggs. Depending in the housing systems, the hens require different diet.

8. In order to improve the production methods, more research is needed about the characteristics of native hens.

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