ORIGINAL ARTICLE

Physical quality of different industrial versus non-industrial eggs obtained from groceries and markets in southern Chile

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ABSTRACT. The aim of this study was to determine external and internal quality parameters of industrial (cages and cage-free) and family farms eggs that are normally available at groceries in developing countries such as Chile. Two experiments were performed to evaluate 1) quality differences between family farms and industrial eggs and 2) to determine quality differences between brown shell eggs from different industrial cage and cage-free systems. Experiment 1 consisted of five groups where three of them were industrial eggs: i) cage white shell eggs, ii) cage brown shell eggs, iii) brown shell cage-free eggs; and two of them were non-industrial: iv) family farm brown shell eggs and v) family farm blue shell eggs. Experiment 2 had four groups, all brown-shell types of eggs were used: i) cage brown eggs, ii) cage-free from aviary eggs, iii) southern free-range eggs and iv) central free-range eggs. In both Experiments, egg weight, egg length, egg width, egg shape index, Haugh units, albumen ratio, egg yolk, yolk weight and albumen weight, blood and meat spots were determined. In Experiment 1, brown and blue-shelled family farm eggs were equal in terms of external and internal quality, except for blood spots, with brown eggs having more incidence. In Experiment 2, free-range eggs presented more intense yolk colors compared to those from battery and cages. In both experiments, free-range eggs presented the darker yolk color. It can be concluded that brown and blue-shelled family farm eggs are equal in terms of external and internal quality, except for blood spots, with brown eggs having more incidence. In addition, free-range eggs from the southern part of the country presented better shell quality, whereas free-range eggs presented more intense yolk colors, while those of battery.

Keywords: egg quality, industrialized eggs, cage-free eggs, free-range eggs, farm eggs.

INTRODUCTION

Egg production systems in the world are developed under conventional (cages) or alternative (cage-free) systems with different housing systems, productive parameters, egg quality, animal welfare and hen's health parameters (Wang *et al*., 2009; Sosnówka-Czajka *et al*., 2010; Rakonjac *et al*., 2014). Furthermore, the alternative systems can be further classified as indoor (i.e., floor, aviary and furnished cages) and outdoor (free-range and organic). Both free-range and organic outdoor systems have daytime access to pasture and some different conditions may exist across world regions. For example, in the European Union (EU) these systems must provide hens daytime access to open-air runs covered by vegetation keeping a density of 2,500 hens/hectare (or 1 hen/4 m2)(EC, 1999) whereas, in the United States, only outdoor access to pasture during the laying cycle is required (Ricke & Rothrock, 2020).

Alternative systems have become increasingly popular among consumers as they prefer animal welfare-friendly systems which also led to the ban on conventional cages in the EU legislation (Chielo *et al*., 2016). Consequently, the alternative egg sector in the world has been growing rapidly in the last 30 years (Hammeishøj, 2011). In Europe, 21.7% of layers are raised in free-range (16.4%) and organic (5.3%) systems, while in Australia 48% of eggs sold at the grocery are free-range (Ruhnke, 2015). It is estimated that globally, egg consumption will continue increasing due to a growing number of people who are adopting meat-free or vegetarian diets (Réhault-Godbert *et al*., 2019).

In Chile, 98.2% of the eggs sold at the market are produced in cages, while 1.2% are cage-free (Aguirre & Pizarro, 2018). Eggs sold at the supermarket are "industrial" since they are produced in cages and cage-free (aviary, floor, free-range and organic) systems. In most of those systems, hybrid hens (crossbred between breeds) have been selected for greater egg production and quality during the last 70 years (Thaxton *et al*., 2016). Thus, the egg industry is based on hybrids (commercial genetic lines) rather than pure breeds as the productivity of a pure breed is less efficient as compared to improved genetic lines (Besbes *et al*., 2007). In Chile, the most common genetic lines for industrial egg production are Hy-line and Lohmann which are reared in both cage and cage-free systems. In our country, there is a normative that regulates the egg labeling in many aspects such as the egg classification (Chilean normative 1372 Of. 78 (González, 2019)). Industrial eggs, most commonly sold at supermarkets, are classified the following categories: especial (> 68g), extra grande (61-68g), grande (54-61g).

Non-industrial eggs, such as farming eggs, belong to family farmers. They are defined as an organization for agricultural production that sustains the work of each family member, regardless of land possession, land surface and land destination (Elhawary *et al*., 2005). These systems

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are using local or native breeds which are less efficient and productive (Rizzi & Marangon, 2012; Lordelo *et al*., 2020). Normally, the eggs are for self-supply and sold at fairgrounds or small farmer markets. In general, these indigenous chickens are double purpose hens fed with pasture, kitchen leftovers, and mixed grains (Elhawary *et al*., 2005). Furthermore, in the specific case of Chile, indigenous hens have been introgressed with the oocyan gene from the Mapuche fowl which produces eggs with a blue/green shell color (Alcalde, 2015).

Berkhoff *et al*. (2020) reported that brown and blue-shell farm eggs are more favorably evaluated and preferred over industrial eggs from free-range and cage-free systems, by 30 untrained panelists in a sensory evaluation. The yolk color was the most important factor for the panelists when discriminating eggs from different production systems. Although, studies have reported how production systems affect egg quality (Stojanova *et al*., 2016; Gałązka-Czarnecka *et al*., 2019), to the best of our knowledge the comparison in terms of internal and external quality traits from industrial, cage-free and family farm eggs have not been evaluated in developing countries where these productions are more available. Such information is important due to the incipient internal market for these eggs (Patterson *et al*., 2001) and the expected increases in production (Aguirre & Pizarro, 2018).

Due to the aforementioned background, the main objective of this study was to determine external and internal quality parameters of industrial eggs (cage and cage-free) and family farms eggs that are normally available at groceries and fairs in developing countries such as Chile. To do that, two different experiments were carried out 1) to evaluate the quality differences between family- farms eggs and industrial eggs and 2) to elucidate quality differences between brown shell eggs from different industrial systems available at groceries.

MATERIAL AND METHODS

The study was carried out at the Animal Nutrition Laboratory of the Animal Production Institute, Universidad Austral de Chile. Two experiments were carried out to evaluate external and internal quality of eggs purchased from different supermarkets, grocery stores, mini markets, and producers. Experiment 1 was carried out between May and June 2018 while Experiment 2 was performed from October to December 2018.

EXPERIMENT 1: FAMILY-FARM VERSUS INDUSTRIAL EGGS

In Experiment 1, a family-farm focused on poultry production was defined as "owner of poultry for personal consumption or local sale with less than 500 birds" (SAG, 2016), thus they are considered non-industrial.

Five different groups were established, three of them with industrial eggs: i) cage white shell eggs (cage white); ii) cage brown shell eggs (cage brown); iii) brown shell cage-free eggs (cage-free); and two of them with non-industrial eggs: iv) family-farm brown shell eggs (farm brown); and v) family-farm blue shell eggs (farm blue). The industrial eggs were obtained from supermarkets (from the same brand and same expiration date) and farm brown and farm blue eggs from local farmer markets (produced in small-scale family farms). Collected farm brown and blue eggs were laid within a maximum period of 4 days and had no expiration date or brand. For each group, a dozen of eggs was purchased at five consecutive weeks, thus 60 eggs per group were subjected to egg quality measurements.

EXPERIMENT 2: BROWN SHELL EGGS FROM DIFFERENT INDUSTRIAL CAGE AND CAGE-FREE SYSTEMS

Four different groups were established, all brown-shell type of eggs were used: i) cage brown eggs (cage); ii) cage-free from aviary eggs (aviary); iii) southern free-range eggs; and iv) central free-range eggs. Free-range eggs differed in their geographical location (central and southern regions of Chile) as climate conditions affect pasture characteristics and therefore may affect egg quality. For each group, a dozen of eggs was purchased at five consecutive weeks, thus 60 eggs per group were subjected to egg quality measurements. All eggs were obtained from supermarkets (from the same brand for each group and similar expiration dates for all groups). The eggs of each group were subjected to the same measurements of external and internal quality.

For experiments 1 and 2, the following measurements were performed to establish external and internal egg quality three hours after purchase.

EXTERNAL QUALITY

Egg weight (EW) was measured using an electronic balance (Q-DG2000, Quimis®, Sao Paulo, Brazil) (+0.05). Egg length (EL) and egg width (EWi) were measured using a digital electronic caliper, and egg shape index (ESI) was computed as:

$$ESI = (EWi/EL) * 100$$

Eggshell weight (ESW) was determined by carefully separating the shell from internal membranes and oven-dried at 105°C for 24 hours. Afterward, eggshells were weighted, and the ESW/EW ratio was reported as a percentage.

$$\%\ shell = (ESW/EW) * 100$$

INTERNAL QUALITY

After break, eggs were inspected for the incidence of blood and meat spots and those were counted. Albumen quality was assessed with Haugh units (HU) and the albumen ratio (AR). First, thick albumen height (AH) was measured with an electronic caliper, and further divided by EW. The HU is a logarithmic result between the EW and the thick albumen height using the following formula: First, thick albumen height (AH) was measured with an electronic caliper, and further divided by EW (Eisen *et al*., 1962). The formula for calculating the Haugh unit is:

$$HU = 100 * \log (h - 1.7w^{0.37} + 7.6)$$

Where:

HU = Haugh unit
h = observed height of the albumen in millimeters
w = weight of egg in grams

Egg yolk (EY) quality color was measured using the DSM YolkFan^{TM}, which is an industrial color scale varying from 1 (pale yellow) to 16 (dark orange) (DSM, 2021). The yolk was carefully separated from the albumen and weighted determining yolk weight (YW) and albumen weight (AW). Yolk height (YH) was determined using an electronic caliper and yolk ratio (YR, %) was calculated as YW/EW, whereas albumen ratio (AR, %) as AW/EW.

STATISTICAL DESIGN AND STATISTICAL ANALYSIS

Two different completely randomized block designs, with five (experiment 1) and four (experiment 2) groups were performed. Five dozen of eggs were analyzed for each group, considering the dozen as the experimental unit, and the egg was considered as the observational unit. Each dozen was analyzed on different sessions.

The data of the quality parameters obtained from the eggs were analyzed with the mixed procedure of SAS (version 9.4; SAS Inst. Inc., Cary, NC), considering the fixed effect of the type of egg and the random effect of dozen and place where eggs were obtained. Statistically significant differences ($P \leq 0.05$) between least square means were tested using the PDIFF command, incorporating the Tukey test for pairwise comparison of group means. The statistical model used was: $Y_{ij} = \mu + \tau_i + \beta_j + \varepsilon_{ij}$. Where: μ = mean, τi = effect of group I, βj = block effect j, and εij = experimental error.

For the incidence of blood and meat spots, data were analyzed as binary and discrete dependent variables, where 0 represented the absence and 1 the presence of blood and meat spots, and results were expressed as logit values. Data were analyzed with the GENMOD procedure of SAS with the DIST = BIN and LINK = LOGIT defining a binomial distribution and a logit model:

$ni = \log[pi/(1-pi)] = m + \tau i$, where p corresponds to the probability of success, m is the overall mean of the proportion on the logarithmic scale and τi the effect of group i

RESULTS

EXPERIMENT 1

The external and internal quality results of experiment 1 are shown in Table 1. The EW was heavier in the cage brown, cage-free, farm brown and farm blue compared with the cage white. Egg length of farm blue and farm brown eggs was longer than the cage-free, cage white and cage brown. However, the cage brown and cage-free eggs were significantly wider than the cage white (P = 0.046) and showed no differences with the farm blue and farm brown eggs. Regarding to ESI and shell percentages, they

Table 1. External and internal egg quality parameters from industrial white and brown shelled cage eggs, free range eggs versus blue and brown shell farm eggs with sixty eggs per group.

	Cage white	Cage brown	Cage- free	Farm brown	Farm blue	P-value	SEM
Egg weight, g	57.5^b	60.9^a	61.7^a	63.0^a	62.1^a	0.018	1.09
Egg length, cm	55.8^b	56.9^b	56.5^b	59.1^a	58.2^a	<0.001	0.43
Egg width, cm	42.8^b	43.7^a	44.2^a	43.6^{ab}	43.7^{ab}	0.046	0.31
Shape index	76.8^a	76.9^a	78.3^a	73.8^b	75.2^b	<0.001	0.54
% Shell	9.0^a	9.8^a	9.9^a	8.8^b	8.55^b	<0.001	0.15
Haugh units	87.1^a	80.3^{bc}	75.5^c	85.0^{ab}	81.9^{ab}	0.013	2.34
Albumen ratio	9.90^a	8.26^{ab}	7.06^b	9.7^a	8.94^a	0.017	0.60
Yolk color	7.8^c	8.4^c	12.8^a	10.6^b	11.0^b	<0.001	0.51
Yolk ratio	46.1	44.8	45.6	46.7	46.9	0.737	1.24
Blood spots	26.4(0/50)^b	1.87(8/59)^a	1.54(10/58)^a	1.01(16/60)^a	2.90(3/59)^a	<0.001	0.59
Meat spots	4.08(1/50)^b	1.29(13/59)^a	0.86(29/58)^a	0.48(23/60)^a	1.24(13/59)^a	<0.001	0.31

$^{a, b, c}$ Different letters indicate significant differences (P < 0.05); SEM = standard error of the mean. ( ) Numbers in brackets indicate the number of eggs with spouts from the total evaluated.

Table 2. External and internal egg quality parameters from brown shelled eggs from different housing origins using sixty eggs per group.

	Cage	Cage-free	Southern free-range	Central free-range	P-Value	SEM
Egg weight, g	59.9	61.0	59.7	61.5	0.664	1.23
Egg length, cm	56.7	56.8	55.8	57.2	0.473	0.62
Egg width, cm	43.6	44.0	43.5	43.9	0.454	0.28
Shape index, %	76.9	77.6	78.0	76.8	0.452	0.56
Shell percentage, %	10.0	10.1	10.2	10.3	0.823	0.19
Haugh units	78.9[a]	66.4[b]	82.3[a]	79.8[a]	<0.001	3.48
Albumen ratio	7.8[a]	5.30[b]	8.6[a]	8.19[a]	<0.001	0.61
Yolk color	9.9[c]	11.3[b]	14.0[a]	14.1[a]	<0.001	0.45
Yolk ratio	41.8	41.4	42.9	41.8	0.398	1.00
Blood spots	-1.07(15/59)	-1.26(13/59)	-1.79(7/49)	-2.2(5/52)	0.113	0.470
Meat spots	-1.08(15/59)[b]	-0.24(26/59)[a]	0.20(27/49)[a]	-1.70(8/52)[b]	<0.001	0.29

[a, b] Different letters indicate significant differences (P < 0.05); SEM = standard error of the mean. Numbers in brackets indicate the number of eggs with spouts from the total evaluated.

were lower for farm blue and farm brown when compared with cage white, cage brown and cage-free eggs.

Haugh units were greater for cage white eggs compared with cage-free and cage brown eggs (P = 0.013). This agrees with the results of the albumen ratio, where cage white along with farm blue and farm brown eggs also had a greater ratio compared with the cage-free eggs (P = 0.017). The YC differed among types of egg (P <0.001), where cage-free were more intense (redder) than those from the farm (blue and brown), and the YC of the farm eggs was more intense than the cage brown and white (more yellow) eggs. The YI was not affected by groups. No differences were found among groups in the yolk ratio (P > 0.05).

The appearance of meat and blood spots was lower in cage white eggs compared with all other eggs.

EXPERIMENT 2

The external and internal quality of brown eggs from different industrial systems are shown in Table 2. There were no differences among groups (P > 0.05) for EW, EL, EWi, ESI and % eggshell.

Results of internal quality are shown in Table 2. There was no difference in the YR among groups (P > 0.05). For HU and AR, aviary eggs showed the lowest values compared with eggs from free-range cage systems (P < 0.001). The YC was greater in eggs from both free-range systems, followed by aviary eggs and, cage eggs showing the lowest values (P < 0.001). The appearance of blood spots was not affected by housing system (P = 0.113). Meat spots were higher in aviary and southern free-range eggs compared to cage and central free-range (P < 0.001).

DISCUSSION

White-shelled eggs in experiment 1 had the lowest weight, which agrees with Curtis *et al*. (1985). Brown hens are larger than white hens, therefore they lay heavier eggs (Odabasi *et al*., 2007). Egg weight is related to hen's age and laying week, as the age of the hen flock increases, the weight of the eggs also increases (Fletcher *et al*., 1981). This explains the fact that white-shelled eggs from cage systems were lighter. Eggs from birds of greater live weight have a longer length and width, which allows us to support that there is a close relationship between the size of the bird and the dimensions of the laid eggs (Idahor, 2017). In Experiment 1, the greater weight and dimensions of family farm eggs may be explained since family farm egg systems in general cull their hens at irregular times, so, their flocks are age-mixed (Asencio, 2023).

In experiment 2, no differences were detected between egg weights under different production systems and the reason for this might be, in agreement with the aforementioned authors, that all the eggs used were brown in color and uniform in size and they all fall into the large classification (between 54 and 61 g), as proposed by the National Institute of Standardization (Chilean normative 1372 Of. 78 (González, 2019)). Also, no differences between egg length and width were detected under the different production systems, which may be because all the eggs used in this experiment came from specific genetics lines, so it is inferred that they are similar in live weight, laying week and therefore in the size of their eggs (Kingori, 2011; Idahor, 2017).

Although the shape index increases with the hen's age, the results found in Experiment 1 showed that family farm eggs have a more elongated shape, while eggs from intensive systems are rounder. As mentioned before, family farm hens have a higher average age than those from intensive systems, so it should be expected that their eggs have a higher morphological index (Lordelo *et al*., 2020). However, results from Experiment 1 agree with Rodríguez-Navarro *et al*., (2013) who indicated that the age of the hens has a significant influence on the shape index of the eggs, as flocks of 77-week-old produced more elongated eggs as compared to 21 to 44 weeks when the egg was more rounded. This could be explained by the fact that, at the beginning of the laying period, eggs have a round shape that gradually tends to lengthen which is due to a weakening of the muscle tone of the calcareous gland in older hens (Travel *et al*., 2010)

A strong eggshell is fundamental for consumers due to the egg's ability to resist shock (Rehault-Godbert *et al*., 2019). Eggshell quality is influenced by genetics, nutrition, environment and the flock age (Samiullah *et al*., 2017) as well as the sanitary condition (presence of infectious bronchitis virus, Influenza, and mycotoxins (Roberts *et al*., 2011). As the hen gets older, egg size and weight increase, and the eggshell does not increase in the same proportion, so it is highly expected that the percentage of eggshell over the egg weight decreases with age and laying week. The lower eggshell percentages in family farm eggs (either blue or brown) observed in Experiment 1 may be explained due to a calcium deficiency in the diet, as calcium is the most important nutritional factor for shell formation and must be supplied in the diet (Nys & Le Roy, 2018). Commercial layers are given a strictly formulated and balanced diet so that each nutrient, including calcium, is delivered as required, this may explain why eggs from intensive systems had a higher percentage of the shell. On the other hand, in the family farm system, birds are fed with a diet whose nutritional profile is often unknown, and where the main source of calcium is oyster shell, which is delivered *ad libitum* (Asencio, 2023). A study conducted with family farm hens pointed out that, in this system, hens receive a diet based on grains with limitations of calcium and phosphorus, for the same reason that there is a greater probability in these hens of having an unbalanced diet that originates eggs with a fragile shell (Juárez *et al*., 2010). It was determined that the greater the value of the morphological index, the greater force is required to break the eggs, so the resistance to fracture is highly dependent on the morphological index (Altuntas & Sekeroglu, 2008).

The eggshell percentage and its proportion related to the EW showed no differences among groups and all eggs were within the expected reference values for good quality, which indicates that the shell should be about 10% of the egg weight (Roberts, 2004). Layers' diets are balanced so the calcium administered is what they need to achieve nonfragile, good quality eggshells, which contributes to commercialization.

Cage white industrial eggs together with family farm eggs (either blue or brown shell) were superior to industrial cage brown and industrial cage-free eggs, whereas, in experiment 2, differences were found between cage eggs and southern and central free-range eggs which obtained a greater value for HU. The albumen ratio followed the same differences in experiment 2 and a little difference was observed for Experiment 1 where family farm eggs, and industrial white eggs were superior to industrial free-range eggs. In experiment 2, the aviary (non-cage) eggs obtained the smallest height and the largest diameter. Other factors influence albumen quality such as age, genetic line and storage conditions, and hen's nutrition (Scott & Silversides, 2000; Huang *et al*., 2012; Chang-Ho *et al*., 2014; Ramírez *et al*., 2016). As the hen gets older, the albumen quality decreases and days between oviposition and consumption or quality evaluation influence this quality parameters (Padhi *et al*., 2013). In both experiments we had no access to flock age records, however, the three industrial systems had the same oviposition-evaluation days that were longer concerning family farms eggs (Roberts, 2004; Chang-Ho *et al*., 2014). Also, it is known that older birds produce thinner eggshells and therefore may lose more CO_2 which causes an increase in the pH of the albumen (Alleoni & Antúnez, 2005). Since family farm eggs had less eggshell percentage, it is believed that greater UH was due to the days between oviposition and egg quality evaluation. The increase in pH in the albumen implies a degradation of the union of the ovomucin and lysozyme proteins, which makes the albumen more and more fluid. In this regard, the pH of the albumen of a freshly laid egg is between 7.6 and 8.5, which can increase to 9.7 after a storage time due to the loss of CO_2 through the pores (Coutts & Graham, 2007).

Also, a genetic effect on albumen quality was reported by Silversides & Scott (2000) who compared a white and brown genetic line, and found a higher albumen height, and therefore a higher UH value in the eggs from white lines. A third factor affecting the albumen quality is storage conditions such as duration and temperature, since an increase in storage temperature led to a significant decrease in HU (Chung & Lee, 2014). Moreover, as egg conservation time increases, the HU and albumen index decrease (Ramírez *et al*., 2016). The hen's nutritional status also affects albumen pH, as it implies a degradation of the union of the ovomucin and lysozyme proteins, which makes the albumen more fluid (Huang *et al*., 2012).

Yolk color is one of the most important parameters of egg preference (Skrivan *et al*., 2015; Berkhoff *et al*., 2020). The results of experiment 1 showed that free-range eggs obtained the highest value for color (the darkest) when compared to family farm eggs and these were darker than white cage and brown cage eggs. Moreover, free-range eggs in Experiment 2 showed the greatest value for yolk color as compared to aviary and cage eggs. These results are consistent with Van den Brand *et al*., (2004) who reported that yolk's color was considerably darker in free-range eggs rather than in cage eggs, since eggs produced under laying hen grazing systems may increase yolk redness (Skrivan *et al*., 2015). Variations in the yolk color are mainly due to the sources of pigmentation (natural or synthetic) (Titcomb *et al*., 2019). For example, Bovšková *et al*. (2014) observed a particularly high content of carotenoids in the eggs of hens raised at home, which is similar to family farm eggs, corroborating what was determined in this study. In the case of pasture systems, yolk egg redness from free-range hens is increased by natural pigment sources such as carotenoids (lutein, beta-carotene, zeaxanthin, among others) compared to a concentrate diet based on corn and soybean meal (Mugnai *et al*., 2014). Among cereals, corn is the only one with a considerable content of beta-carotene (Çalişlar, 2019), which is one of the best sources of energy for poultry producers due to its high metabolizable energy, palatability and digestibility (Rostagno *et al*., 2017).

Hens in an industrial cage and cage-free systems have corn as the basis of their diet, thus, it can be inferred that this cereal by itself does not generate such pigmented yolks (Seemann, 2000). For the yolk index, no differences between groups were observed in experiments 1 and 2. However, Khan *et al*. (2013) found that the yolk index values showed a significant decrease with increasing egg storage period. Opposite to albumen ratio, the decrease in yolk index occurs slower, showing changes in three weeks after the eggs were kept at 25°C (Romanoff & Romanoff, 1949; Elhawary *et al*., 2005; Khan *et al*., 2013). The fact that no differences were found in experiments 1 and 2 may be because all eggs were purchased within less than three weeks between oviposition and evaluation.

Meat spot incidence was greater than blood spots for all types of eggs, which coincides with Stadelman *et al*. (1952), who found that the percentage of meat spots was four times greater than that of blood spots. There was also an increased incidence of both kinds of spots as the hen gets older (Bustany & Elwinger, 1987; Ahmadi & Rahimi, 2011). These could be a valid explanation for family farm eggs, given that there is a great probability that the diet did not meet the nutritional requirements. However, according to the results of experiment 1, blood spots were greater in industrial cage-free, cage brown and family farm brown eggs with respect to industrial cage white and family farm blue eggs. In this regard, hen genetics has been shown to affect the presence of spots (Ahmadi & Rahimi, 2011). In addition, Jeffrey (1950) found that spots were very common in brown eggs of heavy breeds, much less common in lighter eggs, such as blue shell eggs, and rare in white eggs, which is in agreement with our study where white eggs showed a lower incidence of spots (Bustany & Elwinger, 1987). The aforementioned support results of experiment 1. In experiment 2, there were differences between the incidences of meat spots under the different systems, being higher in aviary and free-range eggs from the southern, and lower in eggs obtained under cages and central free-range system, while the blood spots were largely found in the cage eggs, then in aviary, and to a lesser extent in both the free-range systems.

Some aspects of this study need to be considered when interpreting and extrapolating our data. Although data obtained and discussed in the present study shows differences somehow attributed to the different retail points (i.e., supermarkets, grocery stores, and mini markets) where samples were obtained, further information will be needed to complement our findings. In this regard, data on age and hen's genetic line as well as ingredients and chemical composition of animal's diets, egg storing conditions and egg packing should be further analyzed. In this study, those details were not available as our approach was a retail survey.

In addition, further studies should increase the number of companies sampled as well as increase sampling time to reflect if there is a seasonal effect. Previous studies have done similar approaches sampling only 2 local groceries with 2 sampling times allowing us to reach far conclusions on the physical quality and composition of retail shell eggs (Jones *et al*., 2010). In a more recent study, Hisasaga *et al*. (2020) performed a survey of egg quality in commercially available table eggs evaluating 5 brands of brown eggs with 2 sampling periods spanning 7 months. Compared to the aforementioned studies, ours has more complexity as eggs were surveyed not only from industrial origin but also from informal markets where specific egg data is not available or even recorded by retailers. This should be taken into consideration and future efforts in Chile could focus on specific markets and retail types to obtain more data that could help to improve interpretation from laboratory analysis.

CONCLUSIONS

Brown and blue-shelled family farm eggs are equal in terms of external and internal quality, except for blood spots, with brown eggs having more incidence. Family farm eggs are different from those produced in cage and cage-free systems. However, it cannot be said that they are of higher quality, in general terms the main advantage of field eggs is that they are consumed fresh, with their quality attributes still intact. The family farm eggs were larger and wider, had fewer shells in relation to the total weight and had a yolk color of intermediate intensity between the intensive traditional systems. The factor that may have the greatest impact on the quality of these eggs is the less time spent during storage.

It can be concluded that free-range eggs from the southern part of our country presented better shell quality. The free-range eggs, regardless of the regional zone where they are produced, presented more intense yolk colors.

Results from this study could be used as an example of what could be found in terms of internal and external quality traits from eggs produced in developing countries where several systems are available but not much information is available for consumers.

AUTHOR CONTRIBUTIONS

Conceptualization, M.G.; methodology, M.G, and V.O.; software, J.P.K.; validation, M.G., V.O., and J.P.K.; formal analysis, V.O.; investigation, M.G., and V.O.; resources, M.G.; data curation, J.P.K.; writing —original draft preparation, V.O., and E.V.-B.-P. writing— review and editing, M.G., J.P.K and E.V.-B.-P.; visualization, E.V.-B.-P.; supervision, M.G. project administration, M.G.; funding acquisition, M.G. All authors have read and agreed to the published version of the manuscript.

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CONFLICTS OF INTEREST:

The authors declare no conflict of interest.

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