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Study of retail egg supply chain for quality in relation to level of sanitization and farm of origin

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Abstract: In the present cross-sectional study, eggs collected from retail outlets were analyzed for physicochemical and microbial quality. Comparisons were made between "sanitized" (cleaned, sanitized, and retailed after packaging) and "unsanitized" (not subjected to cleaning, sanitization, and packaging) retail table eggs that originated from "commercial" and "backyard" (eggs retailed loose without any cleaning, sanitization, or packaging) farms. A total of 1120 eggs collected from retail markets were analyzed for physicochemical (weight, shell thickness, shape, yolk index, albumen index, Haugh unit, color, and pH) and microbial (total viable count, and yeast and mold counts) characteristics. Eggs collected from retail markets were found to significantly differ with respect to weight, shell thickness, yolk index, albumen index, Haugh unit, yolk color, and total viable counts ($P < 0.01$), but not shape index, pH, or yeast and mold counts. Discriminant analysis corroborated the categorization of table eggs and results of the present study showed differentiation of origin of table eggs based on physicochemical characteristics whereby processed eggs possessed better microbial quality attributes than unprocessed and backyard eggs. Processing of table eggs encompassing hygienic handling, cold storage, and treatment of eggs would deliver wholesome eggs to the consumers through the retail table egg supply chain.

Key words: Egg, Haugh unit, shell thickness, shape index, microbial quality

1. Introduction

Table eggs form the diet of millions of people worldwide owing to their protein composition and essential nutrients (lipids, vitamins, and minerals). About 10%–12% of the recommended daily allowance of protein could be met from eggs due to their high biological value (96%). Owing to health benefits, the egg segment has emerged as a paramount subsector of the economically expanding domain of the poultry industry. In addition to nutritional value, eggs could be potentially converted into value added products like whole egg powder, albumen flakes, yolk powder, and other valuable products. Such products are used as ingredients in a variety of food products (bakery, mayonnaise/salad dressings, ice cream, pastas, and other convenience foods) due to the egg's unique functional properties (gelling, foaming, and emulsion stabilization) [1].

The consumer's first impression of table eggs at purchase is based on freshness or physical perceptions (qualities) like soundness of shell, shape, texture, color, and cleanliness [2]. Unlike external quality, the internal quality of an egg begins to decline soon after it is laid; factors associated with management, nutrition, handling, and storage conditions (time and temperature) affect the egg's internal quality [3,4]. The internal quality of an egg is linked to albumen and its relative viscosity, shape and firmness of yolk, depth of air cell, presence or absence of meat and blood spots, pH, and Haugh unit (HU); among these, the Haugh unit has been construed as a standard for the determination of the internal quality of an egg. The rate at which egg quality declines is measured in HU [5]; hence, HU has emerged as a measure of albumen quality, which is affected by storage conditions and duration. Functional properties of eggs predominantly depend on the physicochemical qualities of egg contents [6,7].

Eggs are also susceptible to microbial proliferation owing to their nutrient composition. Apart from physicochemical indices, microbial quality also determines table egg consumer and functional attributes. It also fairly reflects on practices followed throughout primary production (birds, litter, egg crates, etc.), processing, transportation, and storage [8,9]. Moreover, multiplication of microorganisms within the egg reduces shelf life. Increased incidences of

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spoilage affect public health and make eggs vulnerable to rejection during trade [10]. Poor physical condition of the egg cuticle and underlying shell characteristics (shell and shell membranes) favor microbial penetration [11,12]. The presence of water on the shell and the concentration of iron in the water that comes in contact with the egg, or contamination of the eggshell with organic material such as feces, also affect the microbial quality of the egg [13]. Viable bacterial cells indicate decreased quality, hygiene, and sanitation practice in the production of eggs. In order to maintain nutritional or functional properties, table eggs must be properly handled from oviposition until the final consumption, a period that span days to weeks [14,15]. Market location, storage conditions, and production systems affect consumers' preference for eggs and such practices vary widely from region to region [16].

Retail table eggs in the Indian market scenario could be broadly categorized as eggs originating from commercial layer farms (major contributor) and backyard poultry (minor contributor). A portion of table eggs derived from commercial layer farms enter the processing chain, where eggs are cleaned, washed, sanitized, packaged, and marketed under a brand name (sanitized eggs). However, a major chunk of retail eggs marketed through wholesalers or retailers originate from channels that lack processing and are marketed as loose eggs (straight-run from farm to retailer) without any brand name (unsanitized eggs). Backyard eggs, on the other hand, are eggs collected from free ranging small-scale poultry kept in backyards and such eggs are marketed loose without any treatment. Therefore, the present study was undertaken with the objective of comparing the physicochemical and microbial quality of table eggs originating from different market scenarios under Indian conditions, namely sanitized, unsanitized, and backyard eggs.

2. Materials and methods

2.1. Sampling

Table eggs were collected from local retail markets including supermarkets, provisional stores, grocery shops, and local vendors of different locations of the state of Karnataka in India. Based on the origin of the eggs, samples were categorized into three groups for comparison, as given in Table 1.

Eggs were collected into sterile polybags, transported to the laboratory at ambient temperature, and analyzed for physicochemical and microbial quality attributes on the day of collection. Egg samples were collected from each location on four occasions of 15 days apart, so as to get comprehensive information about the physicochemical or microbial quality attributes.

2.2. Physicochemical analysis of table eggs

A total of 280 table egg samples were analyzed for internal and external quality parameters like weight, shell thickness, shape index, yolk index, albumen index, and Haugh unit.

Eggs were weighed in grams (g) using an electronic balance (Essae, DS-852G). The thickness of the eggshell was measured after removal of membranes using a digital micrometer (Insize Co., Ltd). Three measurements were taken: the first at the broad end of the egg, the second at the middle portion, and the third at its narrow end. An average of three measurements was taken and the eggshell thickness was expressed in millimeters. Egg shape index, yolk index, and albumen index were calculated as described below [17].

Shape index = (whole egg width in mm) / (whole egg length in mm) × 100

Yolk index = (yolk height in mm) / (yolk diameter in mm) × 100

Albumen index = (albumen height in mm) / (albumen diameter in mm) × 100

The Haugh unit (HU) was calculated using the formula of Eisen et al. [18] as a measure of freshness and albumen quality:

$$HU = 100 \log (\text{albumen height} - 1.70 \times (\text{egg weight})^{0.37} + 7.57)$$

The yolk color was graded using Roche color fan (1993 - HMB 50515, printed in Switzerland, 1/0193:10.0) on a scale ranging from 1 to 15. The contents of the whole egg were mixed in a sterile polybag and homogenized in a Stomacher (Bag Mixer, Interscience) for 2 min, and pH

Table 1. Sampling and categorization of table eggs for physicochemical and microbial analysis.

Origin of eggs	Type of treatment (groups)	No. of samples analyzed	
		Physicochemical analysis	Microbial analysis
Commercial farms	Sanitized (cleaned, washed, sanitized, and packed)	160	480
	Unsanitized	80	240
Backyard farms	Unsanitized	40	120
Total		280	840

was measured using a digital pH meter (microprocessor-based digital pH-meter, Systronics).

2.3. Microbial analysis of table eggs

The microbial quality of external egg surface and internal contents (albumen and yolk) of the table eggs were assessed using total viable count (TVC) and yeast and mold counts. The TVC of the external egg surface and internal egg contents were determined using pooled samples (10 eggs) in accordance with the Bacteriological Analytical Manual [19]. Each egg was individually rinsed with 10 mL of sterile phosphate-buffered saline (PBS); the resulting rinsate was pooled into a sterile polybag and homogenized in a Stomacher (Bag Mixer, Interscience), and 10 mL of the pooled rinsate was mixed with 90 mL of PBS followed by serial tenfold dilution in PBS up to 10^{-8}. For internal quality, egg surface was sterilized by rubbing with alcohol, and then egg contents (n = 10) were pooled into a sterile polybag and homogenized in a Stomacher for 2 min to get a uniform homogenate. The resultant 10 mL of homogenate was mixed with 90 mL of PBS followed by tenfold serial dilutions in PBS to reach 10^{-5} dilution. One milliliter of inoculum was drawn from each dilution and placed on sterile petri plates in duplicates. For TVC, autoclaved molten (45 °C) nutrient agar (Hi-Media) was poured into petri plates and rotated in clockwise and counterclockwise directions for uniform mixing; solidified plates were incubated at 37 °C for 24 h. For yeast and mold count, molten Sabouraud dextrose agar (Hi-Media) was used and plates were incubated at 25 °C for 7 days [20]. Colony forming units (cfu) were counted from duplicate plates and counts were expressed per milliliter of sample using the following formula [19]:

$$\mathrm{cfu/mL} = \frac{\sum C}{V \times [n1 + (0.1 \times n2)] \times d}$$

Here, $\sum C$= total number of colonies counted from all plates, n1 = number of plates of lower dilution, n2 = number of plates of higher dilution, d = dilution factor corresponding to lower dilution, and V = volume of inoculum added.

2.4. Statistical analysis

Statistical analysis was performed using SPSS 20.0 (IBM Corp., Armonk, NY, USA) for significant relationships. The physiochemical and microbial qualities of table eggs from different sources were statistically analyzed. Statistical significance was regarded at P < 0.05. Discriminant analysis was carried out for physiochemical parameters with the objective of testing whether the classifications of groups (Y) depend on at least one of the physiochemical parameters (X). In terms of the hypothesis, it can be written as follows: H_0: Y does not depend on any X. H_a: Y depends on at least one X.

3. Results and discussion

The results of physicochemical and microbial analysis of table eggs collected from retail outlets arising from different production and processing systems are shown in Tables 2 and 3, respectively.

3.1. Physicochemical quality of table eggs

3.1.1. Weight of table egg

The weights of eggs sold in retail markets originating from commercial farms were significantly higher than the weights of eggs originating from backyard farms (P ≤ 0.05), as shown in Table 2. The total solid content of a large egg is proportionately higher than that of a medium or small egg [20]; nutrient content also varies proportionally. However, unlike in developed nations, in India eggs are still not marketed based on weight. According to USDA standards [21], eggs obtained from commercial farms could be categorized as "medium" and backyard eggs as "small" or "peewee" type eggs. In India, a separate grade designation is given by AGMARK for table eggs: extra-large (>60 g), large (53–59 g), medium (45–52 g), and small (38–44 g). Based on Indian standards (AGMARK) [22], table eggs originating from commercial farms could be classified as "large" eggs and backyard eggs as "small" eggs. Studies by Al-Obaidi et al. [8] and Yenice et al. [23] also showed larger commercial eggs and small backyard eggs sold via retail outlets.

3.1.2. Shell thickness

Eggshell thickness was significantly higher in eggs obtained from commercial farms than in backyard type eggs (P ≤ 0.05). The thickness of an eggshell depends on genotype and nutritional management of hens; most importantly, dietary manganese, zinc, and selenium influence eggshell thickness [24]. Shell thickness (in mm) observed in the present study for eggs obtained from backyard poultry was in agreement with the observations of Niranjan et al. [25] for Vanaraja and Parmar et al. [26] for Kadaknath breeds, and also for commercial table egg samples reported by Jayasena et al. [27] and Hussain et al. [24].

3.1.3. Shape index

Shape indices of all three groups of eggs in the present study were much closer to the shape index of the standard egg, which is normally recorded at 74 [28], and there was no significant difference in the shape index between retail table eggs originating from commercial and backyard types of poultry farms. Shape index is an important quality attribute required for the industrial packaging of table eggs. Eggs having standard shape offer strength to the eggshell in comparison to oval or sharp eggs, and are also resistant to breakage occurring during transportation and handling [29]. Furthermore, eggs having better shape indexes have also been found to possess desirable egg quality characteristics such as specific gravity, surface area, albumen index, and Haugh unit [30].

Table 2. Physicochemical quality parameters of table eggs.

Parameter	Origin	Sample type	Frequency of collection (15-day intervals)				Mean ± SE
			1st	2nd	3rd	4th	
Weight	Commercial farm	Sanitized	54.01 ± 1.38	55.83 ± 1.48	53.93 ± 1.15	56.10 ± 0.30	54.97 ± 1.08[a]
	Commercial farm	Unsanitized	56.69 ± 1.14	54.73 ± 0.76	53.78 ± 0.88	55.71 ± 0.87	55.23 ± 0.91[a]
	Backyard farm	Unsanitized	36.82 ± 1.02	41.88 ± 0.84	38.91 ± 1.79	42.55 ± 0.91	40.79 ± 1.14[b]
Shell thickness	Commercial farm	Sanitized	0.38 ± 0.00	0.355 ± 0.012	0.32 ± 0.01	0.30 ± 0.01	0.33 ± 0.01[a]
	Commercial farm	Unsanitized	0.38 ± 0.00	0.38 ± 0.002	0.31 ± 0.00	0.33 ± 0.00	0.33 ± 0.02[a]
	Backyard farm	Unsanitized	0.34 ± 0.00	0.25 ± 0.01	0.29 ± 0.01	0.30 ± 0.00	0.29 ± 0.01[b]
Shape index	Commercial farm	Sanitized	76.75 ± 0.31	75.81 ± 0.64	76.25 ± 0.42	76.53 ± 0.93	76.34 ± 0.58[a]
	Commercial farm	Unsanitized	74.75 ± 1.07	74.84 ± 0.87	74.93 ± 0.88	74.75 ± 0.58	74.82 ± 0.85[a]
	Backyard farm	Unsanitized	75.34 ± 0.56	76.34 ± 0.65	72.62 ± 1.77	75.66 ± 0.86	74.99 ± 0.96[a]
Haugh unit (HU)	Commercial farm	Sanitized	70.32 ± 3.78	65.23 ± 2.73	68.18 ± 1.16	61.86 ± 4.25	66.40 ± 2.98[b]
	Commercial farm	Unsanitized	80.76 ± 1.70	79.644 ± 1.13	79.83 ± 1.71	83.17 ± 1.19	80.85 ± 1.43[a]
	Backyard farm	Unsanitized	88.01 ± 0.75	89.72 ± 0.87	89.57 ± 0.54	85.68 ± 0.51	88.24 ± 0.67[a]
Yolk index	Commercial farm	Sanitized	27.80 ± 1.35	31.19 ± 2.00	30.13 ± 2.32	27.79 ± 1.64	29.23 ± 1.83[a]
	Commercial farm	Unsanitized	34.77 ± 1.12	31.03 ± 0.98	33.25 ± 0.99	34.37 ± 0.75	33.35 ± 0.93[ab]
	Backyard farm	Unsanitized	42.93 ± 0.99	37.97 ± 0.51	38.02 ± 0.71	38.00 ± 0.60	39.23 ± 0.70[b]
Albumen index	Commercial farm	Sanitized	5.57 ± 0.81	5.24 ± 0.34	4.96 ± 0.37	4.02 ± 0.41	4.95 ± 0.48[a]
	Commercial farm	Unsanitized	7.81 ± 0.43	6.66 ± 0.34	6.28 ± 0.29	7.42 ± 0.20	7.05 ± 0.32[ab]
	Backyard farm	Unsanitized	8.21 ± 0.26	8.57 ± 0.20	8.52 ± 0.19	8.66 ± 0.28	8.49 ± 0.23[b]
Yolk color	Commercial farm	Sanitized	9.59 ± 0.05	10.63 ± 0.08	9.57 ± 0.09	9.67 ± 0.11	9.86 ± 0.25[a]
	Commercial farm	Unsanitized	9.9 ± 0.14	10.85 ± 0.16	9.88 ± 0.13	10.65 ± 0.15	10.32 ± 0.25[a]
	Backyard farm	Unsanitized	7.40 ± 0.48	7.80 ± 0.44	7.00 ± 0.54	7.10 ± 0.67	7.32 ± 0.53[b]
pH	Commercial farm	Sanitized	7.52 ± 0.09	7.54 ± 0.20	7.43 ± 0.19	7.42 ± 0.13	7.47 ± 0.15[a]
	Commercial farm	Unsanitized	7.73 ± 0.14	7.45 ± 0.14	7.51 ± 0.27	7.39 ± 0.20	7.52 ± 0.19[a]
	Backyard farm	Unsanitized	7.62 ± 0.13	7.70 ± 0.21	7.80 ± 0.15	7.86 ± 0.12	7.75 ± 0.15[a]

Superscript letters indicate significant differences for the corresponding parameters.

Table 3. Microbial quality parameters of table eggs.

TVC of internal egg contents	Commercial farm	Sanitized	3.42 ± 0.17	2.15 ± 0.34	3.06 ± 0.24	4.19 ± 0.14	3.18 ± 0.14[a]
	Commercial farm	Unsanitized	3.76 ± 0.41	4.70 ± 0.10	3.70 ± 0.16	3.05 ± 0.20	3.80 ± 0.04[a]
	Backyard farm	Unsanitized	4.18 ± 0.47	4.77 ± 0.02	4.18 ± 0.32	3.71 ± 0.12	4.21 ± 0.16[a]
TVC of external egg surface	Commercial farm	Sanitized	3.64 ± 0.08	3.16 ± 0.04	4.20 ± 0.07	3.31 ± 0.17	3.58 ± 0.08[a]
	Commercial farm	Unsanitized	5.29 ± 0.39	5.03 ± 0.15	4.90 ± 0.22	5.01 ± 0.19	5.06 ± 0.23[b]
	Backyard farm	Unsanitized	5.61 ± 0.05	5.29 ± 0.37	5.81 ± 0.23	6.12 ± 0.52	5.71 ± 0.17[b]
Yeast/mold count of internal egg content	Commercial farm	Sanitized	2.39 ± 0.06	2.13 ± 0.23	1.74 ± 0.05	1.40 ± 0.09	1.91 ± 0.08[a]
	Commercial farm	Unsanitized	2.50 ± 0.07	2.61 ± 0.12	3.34 ± 0.20	1.97 ± 0.06	2.76 ± 0.17[a]
	Backyard farm	Unsanitized	3.09 ± 0.36	3.27 ± 0.36	2.01 ± 0.01	2.16 ± 0.08	2.63 ± 0.17[a]
Yeast and mold count of external egg surface	Commercial farm	Sanitized	3.06 ± 0.07	2.85 ± 0.07	2.64 ± 0.15	2.71 ± 0.05	2.81 ± 0.33[a]
	Commercial farm	Unsanitized	3.38 ± 0.03	3.12 ± 0.09	3.01 ± 0.20	3.09 ± 0.03	3.15 ± 0.03[a]
	Backyard farm	Unsanitized	4.01 ± 0.28	3.28 ± 0.01	3.32 ± 0.12	3.37 ± 0.24	3.49 ± 0.02[a]

Superscript letters indicate significant differences for the corresponding parameters.

3.1.4. Haugh unit (HU)

Internal egg quality parameters such as albumen index, yolk index, and Haugh unit reflect the fitness of eggs for domestic use. HU is a measure of internal egg quality and has been considered as the gold standard for egg quality assessment [5]. The mean HU of eggs derived from commercial farms was significantly lower ($P \leq 0.05$) than that of backyard eggs. Good quality table eggs have higher HU values of over 70 [27] and the storage of eggs at room temperature (30 °C) for just one day can reduce HU by 10%. Higher HU is also positively associated with the albumen quality of the egg [31]. Table eggs originating from backyard poultry reach retail outlets in a short time, and owing to higher market demand, such eggs are usually not stored. Also, the unsanitized eggs obtained through commercial retailing reach their markets in short times. However, sanitized and packaged eggs that originate from organized and integrated types of commercial establishments take a systematic retail market channel, thereby leading to a considerable span of time of storage and distribution. Hence, such eggs tend to have lower HU than fresh eggs. The study by Jin et al. [32] also showed a dramatic decline in the HU of eggs stored for longer durations (decline in HU from 91.3 to 72.63 when stored at 21 °C and 87.62 to 60.92 when stored at 29 °C for 10 days).

3.1.5. Albumen index and yolk index

These indices indicate the albumen and yolk quality of eggs. Albumen and yolk indices of retailed eggs originating from commercial farms were lower compared to the unprocessed commercial and backyard type eggs. The lower indices could be attributed to longer holding or storage periods at ambient temperature, unlike unprocessed and backyard eggs. This is evident from the results of other reports [26,33]. Akyurek and Okur [33] reported that albumen index and yolk index decreased significantly during a storage period of 14 days at 20 °C and similar results were reported by Kirunda and McKee [34]. Albumen index values ranged from 4.46 to 8.98, with a mean value of 7.03 for the indigenous poultry breed Kadaknath [26]. The strength of the vitelline membrane is responsible for the spherical nature of the egg yolk and is expressed as yolk index. Yolk index values decreased significantly with storage period at 30 °C [27]. The present study showed yolk indices of 29.23, 33.35, and 39.23 for sanitized, unsanitized, and backyard eggs, respectively, on the day of collection. The results of the present study are in agreement with the results of Jayasena et al. [27], wherein eggs from a wholesale market were analyzed. Yolk index values for the indigenous Kadaknath poultry breed range between 35.07 and 38.10 [26].

3.1.6. Yolk color

Color is imparted to the egg yolk by carotenoid pigments. Yolk color varies considerably depending upon the feed ingredients [35]. In the present study, yolk color was significantly better ($P \leq 0.01$) in eggs derived from commercial farms than in backyard eggs. Such variations could be attributed to feeding a balanced feed (xanthophyll-rich) to the commercial layer hens [36]. Other reports showed that yolk color is inversely related to storage time (2, 5, and 10 days at 5, 21, and 29 °C) [27]. It has been reported that the increase in internal temperature and prolonged storage time (30 days) of an egg leads to denaturation of albumen and vitelline membrane structural proteins, which allow water to enter the yolk, which in turn decreases the yolk color due to dilution of the pigment [32].

3.1.7. pH

All types of eggs showed a similar trend in pH, without any significant difference between the groups. Eggs maintained at elevated temperatures for long periods showed an accelerated increase in albumen and yolk pH values, and consequently loss of protein [3].

3.1.8. Discriminant function analysis

Discriminant function analysis was carried out for physicochemical parameters of three different categories of eggs. Individual samples were plotted by their physicochemical scores on the resultant canonical variates. The canonical discriminant function (Figure) displayed the position of individual samples of three groups that had two canonical variates. Classification of discriminant analysis results (Table 4) indicated that 90.4% of the original grouping of cases was correctly classified (Wilk's $\lambda < 0.001$) and the associated eigenvalues were 4.068 and 0.726; percentage of variance was found to be 84.8% and 15.2% for function 1 and function 2, respectively. Most separation was therefore on the first two axes, which were plotted. They indicated three approximate clusters. Slight overlap can be observed between the eggs of the sanitized and unsanitized groups of commercial farms.

3.2. Microbial quality of table eggs sold at retail markets

Determination of the microbial load of table eggs (Table 2) reflects the practices followed in the primary production at farm level and the conditions of processing, transport, and storage of table eggs. External and internal microbial loads of table eggs, as assessed by TVC and yeast and mold count, were lower in commercially sanitized eggs than in unsanitized and backyard eggs. However, only the TVC of the external egg surface of table eggs differed significantly ($P \leq 0.05$) between commercially processed and backyard eggs (Table 2). No significant difference in TVC of internal egg content of commercial (sanitized or unsanitized) and backyard (usually unsanitized) eggs was observed. Likewise, the yeast and mold count was also lower over the egg surface and internal contents in sanitized table eggs

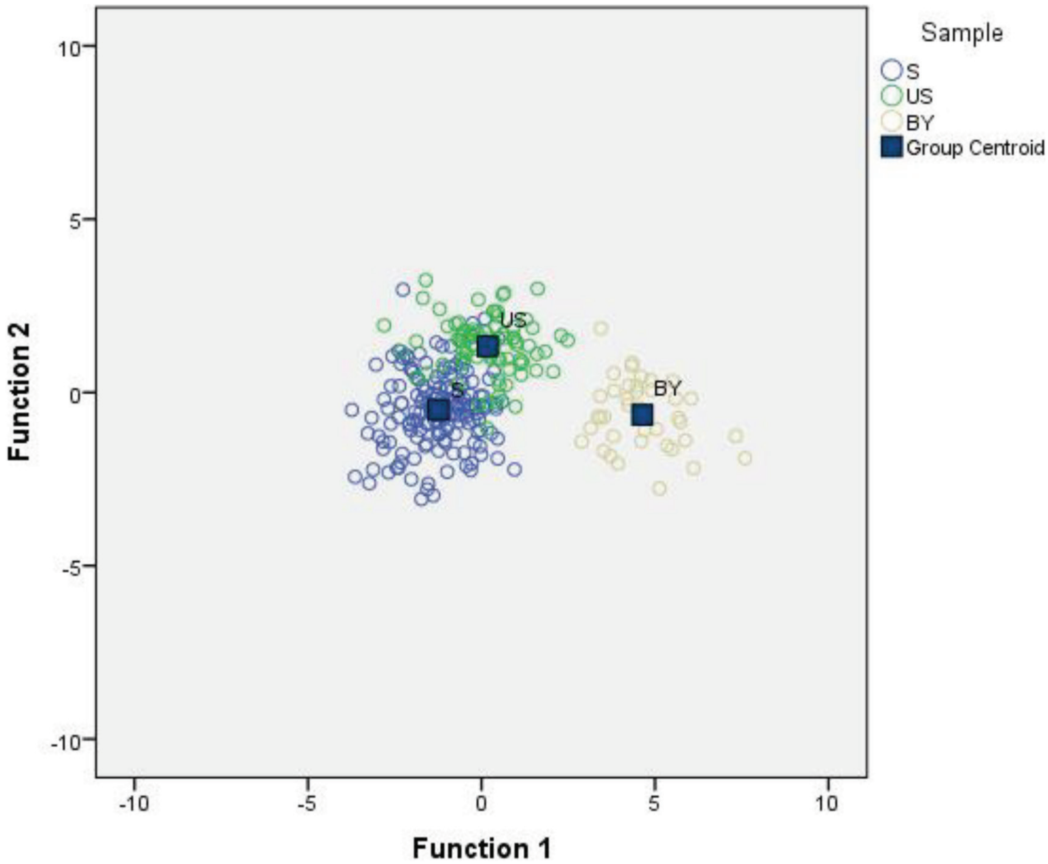

Figure. Canonical discriminant analysis plot for physicochemical parameters of table eggs collected from markets (S: sanitized eggs; US: unsanitized eggs; BY: backyard eggs).

Table 4. Discriminant analysis for physicochemical parameters of table eggs collected from markets.

Sample			Predicted group membership			Total
			S	US	BY	
Original	Count	S	142	18	0	160
		US	9	71	0	80
		BY	0	0	40	40
	%	S	88.8	11.3	0	100.0
		US	11.3	88.8	0	100.0
		BY	0	0	100.0	100.0

S: Sanitized eggs; US: unsanitized eggs; BY: backyard eggs.

originating from commercial farms than in unsanitized commercial farm or backyard eggs.

Environmental conditions play a significant role in microbial quality; a humid environment leads to higher microbial populations in eggs stored under ambient temperature [37,38]. Eggs stored at ambient temperature harbored higher counts of bacteria, yeast, and mold as compared to sanitized and oiled eggs stored at refrigeration temperatures. Drying and shrinkage of the cuticle leads to increased shell pore size and makes it easier for microorganisms to pass into the egg when stored at ambient temperatures [39]. Backyard eggs showed higher microbial loads than sanitized and unsanitized commercial table eggs in the present study. Similar observations were made by Mahdavi et al. [40] and Cader et al. [41]. Nevertheless, microbial loads of table eggs collected from different sources were compliant with the limits recommended by the International Commission on Microbiological Specifications for Foods.

The system of rearing layer hens contributes significantly to the microbial contamination of eggs. Deep litter (floor) housing systems contribute enormously to contamination compared to raised cage systems of rearing. After oviposition, storage environment and temperature also significantly contribute to the growth of microorganisms in and on table eggs [42]. Initial contamination levels of eggshells and egg contents, integrity of shells, storage conditions, and age of eggs critically affect microbial contamination [31]. Breakage of eggs also results in microbial contamination of the surrounding eggshell surface. In view of this, frequent collection soon after laying, on-farm cleaning, sanitization, oiling, packaging, and keeping eggs refrigerated until they reach the consumers are advocated so as to ensure egg quality and safety.

3.3. Conclusions

Eggs are known for their nutritional value and functional properties; preparation of value-added egg-based products is linked to quality. Desirable properties are linked to physicochemical and microbial qualities of eggs. The present study deals with the determination of physicochemical and microbial qualities of table eggs retailed through different retail channels in India. Samples collected from retail markets were found to comply with established national standards. However, discriminant analysis of physicochemical parameters precisely categorized the origin of retailed eggs. The results of the present study indicated a significant impact of sanitization on the physicochemical and microbial qualities of market eggs. A drop in the internal quality of unsanitized eggs originating from backyard farms was noticed. Duration, temperature of storage, and sanitization showed significant effects on microbial load, indicating the advantages of sanitization. The results of the present study underscore the need for implementation of hygienic handling practices and cold storage of retail table eggs for the preservation of desirable qualities across the retail market supply chain.

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