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Research Article

Comparison of Physicochemical Characteristics and Sensory Attributes of Four Different Chicken Breeds from the Genuine and Selected Local Market

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Village chicken is known as a high-quality product perception and sold at high prices. However, the authenticity of village chicken is doubted because colored chicken has been claimed as village chicken to fraud the consumers and to gain high profit. No stringent strategy has been implemented by the local authority on the authenticity of the claimed village chickens. Thus, the study aimed to determine the meat quality of different chicken breeds including village chicken, broiler chicken (Cobb), colored chicken (Hubbard), and layer chicken from genuine suppliers and chickens sold at different local markets based on the physicochemical characterization, textural properties, and sensory evaluation. Chicken breeds were obtained from genuine suppliers and slaughtered at the slaughtering house Universiti Putra Malaysia. Proximate composition, color, and textural properties were evaluated. Minitab-19 and SIMCA-13 software were used to analyze the results, applying analysis of variance and partial least squares discriminant analysis, respectively. The study revealed that some of the market-supplied chickens were not authentic based on the features studied. About 20% of market village chickens had possessed similar results as the control village chicken. It can be shown that 80% of the claimed village chicken sold in the market was not authentic village chicken. This study showed the differentiation in texture composition such as chewiness, hardness, gumminess, cohesiveness, resilience, and springiness, followed by protein content, ash content, and a^* and b^* values as an indicator to differentiate the authenticity of different chicken breeds.

1. Introduction

The poultry industry is the most advanced of the Malaysian livestock sector, with a highly integrated production system. According to the Ministry of Agriculture [1], Malaysia is one of the highest poultry consumers in the world with 49.35 kg per capita consumption as of 2020. About 53.2% of the total livestock production had been contributed to broiler production in 2010 [2]. Chicken meat is greatly accepted by consumers worldwide compared to other meat consumption, and the preference and consumption of chicken meat can be considered as a universal phenomenon. Both urban and rural citizens majorly consume chicken meats in Malaysia [3].

Gallus domesticus is a domesticated fowl that is generally called a bird and is familiar with human provision and control. Chicken is one of the largest provisions of the poultry industry, where chicken meat and eggs are the major products and important sources of food. Chickens that lay eggs for human consumption are termed layer chickens and meat chickens/broilers are termed for breeding and producing meat. There are various breeds of chicken in different geographical locations and primarily they can be divided into three breeds. The three breeds are pure breed, egg-laying breed, and mixed breed. Some breeds are known to be of the best meat producing, and some are reared for laying eggs, while some of them are good in producing both meat and eggs. There are several chicken breeds such as village chicken, broiler chicken, colored chicken, and layer chicken, and their physicochemical composition varies from one to another [3–5].

The native village chicken is known as "Ayam Kampung," which is the chicken breed reported from Malaysia and Indonesia. This indigenous chicken is typically raised using traditional free-range production techniques by almost every household in the village area. In many rural areas, village chickens are the most common type of livestock reared [4, 5]. Ahlers et al. [6] stated that even very poor households with few labor resources will normally keep some chickens. The village chicken is a small dual-purpose chicken that can lay eggs and rear for their meat. The village chicken reaches its market weight of 1–1.5 kg in four to five months for their meat production, which costs more than the commercial breeds. The slow-growing breed of village chicken contributes to its low productivity. Village chickens generally have a slower growth rate than commercial broilers, which may contribute to differences in the properties of their meats. Generally, village chicken possesses a firmer texture, lesser fat, and more flavor, particularly after cooking, compared to commercial broilers [7]. According to Mengesha [8], village chickens also can resist disease, able to utilize low-quality feeds, and are preferred by consumers. Both physical characteristics and the color of their body parts are highly variable. They can be recognized by three principal color combinations and the common one is the black-red variety, in which cocks are mainly green-black with glossy red-brown back, neck hackles, and saddle feathers.

Compared to other animal species, the quality of poultry meat is now of major importance because poultry meat is usually consumed as cuts or processed products rather than as whole carcasses. The quality of poultry meat can be observed by its safety, nutritive value, and sensory characteristics. Meat safety is determined by the degree of microbiological and chemical contamination, while the nutritional quality of poultry meat is influenced by the high-value protein content, unsaturated fatty acids, vitamins, cholesterol, and other biologically active compounds. The essential sensory traits include meat color, aroma, texture, and flavor. Consumers often seek meat that is low in fat, tender, and juicy with a good aroma and flavor [9].

The development of the poultry industry and the importance of the consumption of chicken meat nowadays require a better knowledge and control of the characteristics of the chicken meat. A review of the factors that influence the technological and nutritional quality of chicken meat is essential to have knowledge for developing research and for promoting this poultry meat in the future. The outcomes of this review should be useful for controlling the fundamental quality factors for further development in chicken production efficiency and processing [10]. In general, consumers judge meat quality by its appearance, texture, juiciness, moisture, firmness, tenderness, odor, and flavor.

Therefore, the study is aimed to differentiate the quality of chicken meats between genuine and market chickens of four different breeds namely village chicken, broiler chicken (Cobb), colored chicken (Hubbard), and layer chicken based on their physicochemical characterization, textural properties, and sensory evaluation.

2. Materials and Methods

2.1. Sample Preparation. Chickens of four breeds, including village chicken, broiler chicken (Cobb), colored chicken (Hubbard), and layer chicken were used. The control sample for the four chicken breeds was obtained from the genuine supplier to avoid fraud with a total number of 67 chickens for each breed grouped as a village (CVC, $n = 67$), broiler (CBC, $n = 67$), colored broiler (CCC, $n = 67$), and layer (CLC, $n = 67$). Village chicken meat samples, which were claimed as village chicken meat by the sellers, were collected from ten different markets ($n = 3$, per market: MVC 1, MVC 2, MVC 3, MVC 4, MVC 5, MVC 6, MVC 7, MVC 8, MVC 9, and MVC 10). Samples were collected from three different markets for the colored ($n = 3$, per market: MCC1, MCC 2, and MCC 3), broiler ($n = 3$, per market: MBC 1, MBC 2, and MBC 3), and layer ($n = 3$, per market: MLC 1, MLC 2, and MLC 3). The raw breast fillets (pectoralis major and minor) were used for physicochemical characterization, textural properties, and sensory evaluation, and each analysis was done in triplicate (Figure S1). The frozen meat was thawed at 4°C until a core temperature of 0–2°C was achieved before analysis. The meat was washed thoroughly with running water (4°C).

For the sensory evaluation, about 300 ± 20 g of chicken breast was boiled at 100°C for 20 minutes in a pot with a capacity of 3 L, on an ordinary kitchen stove. All samples were cooked in the same amount of water, at the same temperature and time duration. To ensure boiling at a constant temperature, a temperature probe was used to monitor [11]. The cooked chicken portion was then removed and transferred to a flat aluminum tray and allowed to cool for 10 minutes. Later, the samples were cut into cubes (2 cm), placed into a small container with a lid, and coded with three digits of random numbers for quantitative descriptive analysis and triangle tests.

2.2. Proximate Analysis. The routine proximate analysis was carried out by using the method adapted from AOAC Official Methods to identify the chemical composition of the raw chicken meats. The meat samples were cut into small pieces and homogenized. The moisture content was determined using the oven drying method according to the AOAC 950.46 method [12]. For determining the ash content, the samples in crucibles were placed in the muffle furnace at a temperature of 600°C for at least 4 hours until there was no presence of black ash based on the AOAC 942.05 method [13]. Meanwhile, the crude protein and fat content were determined following the Kjeldahl (AOAC 2001.04) [14] and Soxhlet (AOAC 2007.04) [15] techniques, respectively. All the analyses were carried out in triplicates.

2.3. Color Analysis. The color parameters of raw chicken meats were determined using a portable chromameter (Konica Minolta Chroma Meters CR-400 series, USA) and reported as L^* (lightness), a^* (redness), and b^* (yellowness) values. The samples were cut into pieces of approximately $5 \times 5 \times 1$ cm. The equipment was standardized with a white color standard. The mean value of all measurements was taken for each L^*, a^*, and b^* values [16]. All the analyses were carried out in triplicates.

2.4. Texture Profile Analysis (TPA). Texture profile analysis was carried out by adapting methods proposed by Aguirre et al. [17] and Karthikeyan et al. [18]. The samples were prepared by cutting them to a $3 \times 3 \times 1$ cm measurement and placed on a flat surface before compression using a 75 mm diameter compression plate at a 70% compression ratio. The analysis was carried out using a texture analyzer (Model TA-XT2, Stable Micro-Systems, Surrey, UK). The recorded features include adhesiveness, hardness, gumminess, springiness, cohesiveness, chewiness, and resilience. The parameters of the texture analyser were set based on the study by Karthikeyan et al. [18], with pre-test, test, and post-test speeds of 2 mm/sec, 1.0 cm distance, and automated triggering system.

2.5. Quantitative Descriptive Analysis. The quantitative descriptive analysis was performed using a team of nine panelists recruited. Before the analysis, the team members participated in five group discussions that discussed all the sensory attributes like appearance, texture, flavor, and odor before a final vocabulary is selected and defined (Table S3 and Figure S2). During the evaluation, each panelist was provided with a list of all attributes with their definition and all samples were scored on an unstructured 15 cm line scale in duplicate. To prevent bias effects in the order of sample presentation and carryover within and between days, the order of sample presentation to panelists was balanced [19, 20]. All assessments were conducted at a sensory laboratory at the Faculty of Food Science and Technology, Universiti Putra Malaysia.

2.6. Discriminative Analysis. For the discriminative analysis, each panel was presented with a set of three closed containers containing different three-digit numbers for each. Two of the containers contain the same sample, while one is an odd sample, where the panelists are required to identify the odd sample. Panelists were provided with a cup of warm water and toothpicks to cleanse their plates before each sample are evaluated. All assessments were conducted at a sensory laboratory at the Faculty of Food Science and Technology, Universiti Putra Malaysia.

2.7. Data Analysis. Descriptive and discriminative sensory data were analyzed using partial least squares discriminant analysis (PLS-DA) and one-way analysis of variance (ANOVA) for significance. The ANOVA was carried out using Tukey's test for comparison with a confidence interval of 95% and significance at $p < 0.05$. Samples were prepared in triplicates for all the analyses done; data are reported as mean ± standard deviation. Spider plots were generated to provide a graphical representation of the multivariate data in the form of a two-dimensional chart of three or more quantitative variables.

3. Results and Discussion

3.1. Physicochemical Characterization and Texture Profile of Control Breeds with Market Chickens

3.1.1. Village Chicken. Tables 1–3 summarize the proximate, color, and textural properties of village chicken meats respectively. From Table 1, the protein content of all market samples showed a significant difference ($p < 0.05$) ranging from 13.75% to 18.56% except for markets 2 and 4, which was similar to the control sample. The major similarity of the protein content was related to the feed provided and the outdoor system that contributes to muscle development and high protein of village chicken. This observation is supported by a study from Pambuwa and Tanganyika [21] that reported that the chickens of free range had more protein content (21.49%) compared to chickens raised on the intensive management system. The ash content of control village chickens showed a significant difference ($p < 0.05$) potentially due to the high mineral content in their feed. The control sample and market 4 had similar values, followed by markets 2 and 6 that had slightly lower values from the control sample. Meanwhile, other market samples were significantly different from the control sample. Chepkemoi et al. [22] mentioned that village chickens had higher ash content as they were usually left to scavenge, thus consuming a wider range of food resulting in higher mineral content.

Table 1 also shows a significant difference in the fat content between control and market samples. Markets 2 and 4 portrayed similar results as control, while other market samples had higher values than the control sample. Due to its scavenging and physical effort, village chicken accumulates less fat [21]. Tougan et al. [23] reported that the fat content of chicken meat from confinement was significantly higher than those chickens with a free-range management system. The moisture content showed no significant difference between the control and market samples, but markets 2 and 4 can be classified as similar as control village chicken based on the values displayed in Table 1. It was claimed that due to the age at slaughter, the moisture content reportedly decreases with age [23]. This could be attributed to the growth and maturity of the chicken muscle as village chicken had a slow growth rate [24]. It was similar to the past research that reported that free-range chicken meat had lower fat content, less moisture, and was drier as this breed would actively scratch their feed [25].

In Table 2, the color composition of village chicken meat obtained from a genuine supplier and 10 different markets are listed, where lightness (L^*) values had a significant difference ($p < 0.05$) between control and market samples. Control village chicken had a low L^* value (50.85), which indicates slightly dark meat. Markets 2 and 4 had L^* values near to control, while other market samples were

Table 1: Proximate composition of village chicken meat obtained from a genuine supplier and 10 different markets.

Samples	Proximate composition			
	Moisture content (%)	Ash content (%)	Crude protein (%)	Crude fat (%)
CVC	68.41 ± 0.02^{a}	1.22 ± 0.01^{a}	19.83 ± 0.10^{a}	5.41 ± 0.10^{de}
MVC 1	75.16 ± 0.05^{a}	0.94 ± 0.01^{c}	13.35 ± 0.06^{f}	8.85 ± 0.07^{abc}
MVC 2	69.87 ± 0.03^{a}	1.06 ± 0.02^{b}	19.54 ± 0.10^{b}	5.30 ± 0.20^{e}
MVC 3	74.14 ± 0.02^{a}	0.97 ± 0.03^{c}	14.91 ± 0.06^{e}	9.22 ± 0.97^{ab}
MVC 4	70.33 ± 0.01^{a}	1.16 ± 0.01^{a}	19.70 ± 0.11^{ab}	6.16 ± 1.17^{de}
MVC 5	74.51 ± 0.02^{a}	0.93 ± 0.02^{c}	12.09 ± 0.06^{g}	9.98 ± 0.16^{ab}
MVC 6	72.79 ± 0.01^{a}	1.06 ± 0.02^{b}	17.60 ± 0.10^{c}	8.61 ± 0.09^{bc}
MVC 7	75.99 ± 0.01^{a}	0.74 ± 0.03^{d}	13.35 ± 0.06^{f}	9.94 ± 1.00^{ab}
MVC 8	72.51 ± 0.05^{a}	0.75 ± 0.04^{d}	15.43 ± 0.15^{d}	10.57 ± 0.08^{a}
MVC 9	74.28 ± 0.03^{a}	0.77 ± 0.03^{d}	15.65 ± 0.17^{d}	10.00 ± 1.01^{ab}
MVC 10	75.93 ± 0.01^{a}	0.66 ± 0.03^{e}	13.38 ± 0.06^{f}	7.23 ± 0.05^{cd}

Data are mean ± standard deviation. Means ± SD followed by different superscript letters within the same column are significantly different at $p < 0.05$. *Note*. CVC, control village chicken; MVC, market village chicken.

Table 2: Color composition of village chicken meat obtained from a genuine supplier and 10 different markets.

Samples	Color composition		
	L^*	a^*	b^*
CVC	50.85 ± 0.04^{j}	12.58 ± 0.05^{g}	10.55 ± 0.08^{e}
MVC 1	55.52 ± 0.03^{b}	14.16 ± 0.02^{d}	9.56 ± 0.04^{f}
MVC 2	50.57 ± 0.05^{k}	11.03 ± 0.05^{i}	9.35 ± 0.02^{g}
MVC 3	53.80 ± 0.06^{g}	15.05 ± 0.04^{a}	11.81 ± 0.03^{b}
MVC 4	51.51 ± 0.06^{i}	13.04 ± 0.02^{e}	10.46 ± 0.02^{e}
MVC 5	54.28 ± 0.06^{f}	14.66 ± 0.04^{b}	15.64 ± 0.02^{a}
MVC 6	56.88 ± 0.04^{a}	11.41 ± 0.05^{h}	10.87 ± 0.05^{d}
MVC 7	54.69 ± 0.04^{d}	14.35 ± 0.02^{c}	9.63 ± 0.06^{f}
MVC 8	54.51 ± 0.05^{e}	9.81 ± 0.01^{j}	11.37 ± 0.07^{c}
MVC 9	53.50 ± 0.03^{h}	12.78 ± 0.04^{f}	10.80 ± 0.06^{d}
MVC 10	55.33 ± 0.02^{c}	12.61 ± 0.05^{g}	11.26 ± 0.04^{c}

Data are mean ± standard deviation. Means ± SD followed by different superscript letters within the same column are significantly different at $p < 0.05$. *Note*. CVC, control village chicken; MVC, market village chicken.

Table 3: Texture profile of village chicken meat obtained from a genuine supplier and 10 different markets.

Samples	Texture profile						
	Adhesiveness (g/sec)	Hardness (g)	Gumminess	Springiness	Cohesiveness	Chewiness	Resilience
CVC	-16.91 ± 0.34^{d}	3899.70 ± 189.56^{a}	2300.48 ± 87.09^{a}	0.64 ± 0.03^{a}	0.59 ± 0.01^{a}	1294.52 ± 52.24^{a}	0.43 ± 0.02^{a}
MVC 1	-13.47 ± 0.22^{b}	1032.91 ± 127.99^{cd}	350.07 ± 41.04^{d}	0.46 ± 0.04^{bcd}	0.34 ± 0.01^{ef}	247.72 ± 20.48^{c}	0.25 ± 0.03de
MVC 2	-15.22 ± 0.30^{c}	3865.70 ± 135.41^{a}	1945.06 ± 73.26^{b}	0.52 ± 0.06^{b}	0.51 ± 0.03^{b}	1124.71 ± 116.02^{b}	0.34 ± 0.01^{bc}
MVC 3	-12.28 ± 0.12^{a}	1156.47 ± 91.02^{cd}	387.32 ± 5.88^{d}	0.40 ± 0.02^{cde}	0.34 ± 0.04^{ef}	302.47 ± 14.33^{c}	0.20 ± 0.03^{e}
MVC 4	-15.11 ± 0.09^{c}	3073.36 ± 189.46^{b}	1525.64 ± 84.59^{c}	0.50 ± 0.03^{b}	0.47 ± 0.04^{bc}	1041.97 ± 20.36^{b}	0.34 ± 0.01^{bc}
MVC 5	-13.39 ± 0.19^{b}	1130.53 ± 35.24^{cd}	387.30 ± 24.14^{d}	0.36 ± 0.03^{e}	0.33 ± 0.01^{ef}	318.87 ± 20.35^{c}	0.24 ± 0.02^{de}
MVC 6	-13.37 ± 0.11^{b}	1109.63 ± 39.97^{b}	457.64 ± 18.65^{d}	0.47 ± 0.02^{bc}	0.42 ± 0.02^{cd}	290.11 ± 30.18^{c}	0.31 ± 0.01^{bc}
MVC 7	-12.39 ± 0.07^{a}	925.03 ± 44.43^{d}	313.23 ± 19.60^{d}	0.39 ± 0.03^{cde}	0.33 ± 0.02^{ef}	289.03 ± 34.70^{c}	0.25 ± 0.02^{de}
MVC 8	-13.44 ± 0.09^{b}	1141.57 ± 43.93^{cd}	313.45 ± 5.62^{d}	0.33 ± 0.03^{e}	0.27 ± 0.01^{f}	255.44 ± 15.85^{c}	0.29 ± 0.02^{cd}
MVC 9	-12.70 ± 0.27^{a}	1125.08 ± 48.80^{cd}	349.51 ± 29.63^{d}	0.35 ± 0.01^{e}	0.31 ± 0.02^{ef}	289.18 ± 37.28^{c}	0.23 ± 0.01^{e}
MVC 10	-13.52 ± 0.06^{b}	1306.55 ± 71.27^{c}	446.28 ± 63.23^{d}	0.37 ± 0.01^{de}	0.35 ± 0.03^{de}	306.35 ± 22.57^{c}	0.36 ± 0.02^{b}

Data are mean ± standard deviation. Means ± SD followed by different superscript letters within the same column are significantly different at $p < 0.05$. *Note*. CVC, control village chicken; MVC, market village chicken.

significantly higher and differ from the control sample. The village chicken had a low L^* value, reflecting its darker and redder meat contributed by the amount of myoglobin in the muscles, which increases with chicken age [26].

The intensity of redness (a^*) and yellowness (b^*) of the tested chicken meats was higher in markets 3 and 5 compared to the control village chicken. Similar values of the color properties measured were observed in both market 9 and 10 samples. This difference in meat color can be due to the difference in their slaughter age, which can affect the content of myoglobin and hemoglobin in muscle. According to Gordon and Charles [27], older chickens (slower growing) had redder meat due to a higher content of myoglobin. Lonergan et al. [28] believed that difference in meat redness was due to a difference in muscle fiber type. Du and Ahn [29] observed an increase in protein content and decrease in the fat content of village meat, causing higher texture and values along with less intensive meat color (a^* and b^*). In addition, changes in the meat pH upon slaughtering may alter the color intensity of the meat. Milicevic et al. [30] have mentioned in their study that increased pH of muscle will contribute to dark-colored fillets that subsequently increase the susceptibility to bacterial infections compared to light-colored meat. The meat color intensity is influenced by myoglobin and hemoglobin content, chemical stability, muscle fiber, and meat pH.

The texture profile (Table 3) of village chicken meat is displayed through the attributes including adhesiveness, hardness, gumminess, springiness, cohesiveness, chewiness, and resilience of control; MCV 2 and MCV 4 portrayed similar results, while other markets differ from the control sample. The high content of collagen was known to be related to the texture characteristics of village chicken meat. Collagen is the intramuscular connective tissue that becomes higher and less soluble when the chicken grows more mature or older [31]. According to Lin et al. [32], the high amount of connective tissue was due to the increased physical activity of village chickens in outdoor management. Thus, village chicken contributed to the high value of hardness, gumminess, and chewiness. The study also reported greater chewiness, firmness, and toughness of free-range chickens, which was associated with its high collagen content.

Figure 1 illustrates the score scatter plot (PLS-DA component 1 vs PLS-DA component 2), which showed a good clustering of control and market village chicken samples. The PLS-DA component 1 separates the clusters into 11 groups. Control and market 2 and 4 samples are located on the positive side, while those other markets are located on the negative side. The PLS-DA loading column plot signals corresponding to the clustering based on PLS component 1 are displayed in Supplementary Figure S3. All properties and attributes analyzed were applied in the discriminant analysis that separates the samples based on their corresponding signals. The gumminess, hardness, chewiness, protein, cohesiveness, springiness, ash, and resilience were found to be dominant in the control sample, market 2, and market 4 samples. Meanwhile, adhesiveness, fat, moisture, and color parameters' (L^*, a^*, b^*) values were dominant in markets 1, 3, 5, 6, 7, 8, 9, and 10. The texture attributes such as gumminess, hardness, chewiness, and cohesiveness contributed to a dominant comparison between the control sample and market samples due to the amount of collagen content in the meat. It was associated with high collagen content due to their greater motor activity or increased physical activity [32]. The next parameter that highly contributed to the comparison of control and market samples was protein content due to the high amount of amino acid concentration and exercise in the outdoor system, which leads to muscle development and high protein of village chicken. Ash content also affects the comparison between control and market samples as village chicken is usually left to scavenge, thus consuming a wider range of food resulting in higher mineral content [22].

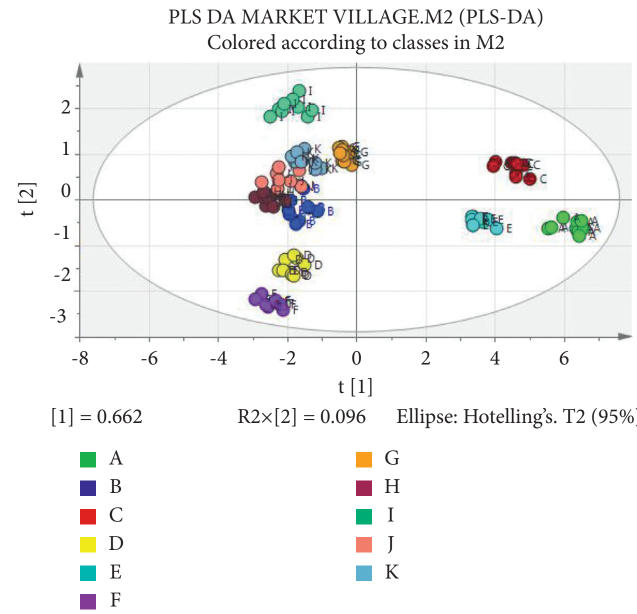

Figure 1: The partial least squares-discriminant analysis (PLS-DA) score plot of control and market samples of village chickens. Colored circles are represented by CVC = control village chicken (green); MVC 1 = market 1 (dark blue); MVC 2 = market 2 (maroon); MVC 3 = market 3 (yellow); MVC 4 = market 4 (light blue); MVC 5 = market 5 (purple); MVC 6 = market 6 (orange); MVC 7 = market 7 (brown); MVC 8 = market 8 (turquoise); MVC 9 = market 9 (pink); MVC 10 = market 10 (grey).

Technically, the properties and attributes applied in the analysis can be implemented to distinguish the authentic village chickens from the claimed ones. The results showed that markets 2 and 4 had major similarities with control village chicken. About 80% of the claimed village chickens sold in the market portrayed different results to the control village chicken in terms of texture attributes such as gumminess, hardness, chewiness, cohesiveness, springiness, protein, and ash content. Thus, it can be related to the problem statement mentioned earlier that the authenticity of village chicken from local markets was doubted. Research done by Lawal et al. [33] supported these results that 90% of the claimed village chicken that was sold in the market was to be colored chicken and not the authentic village chicken.

3.1.2. Broiler Chicken. Tables 4–6 summarize the proximate, color, and textural properties of broiler chicken meats of both genuine and market samples. In Table 4, the proximate composition of broiler chicken meat obtained from a genuine supplier and three different markets are shown. The fat content had a significant difference ($p < 0.05$) between control and market samples as the control sample was slightly higher than other market samples, while all market samples had similar values. The fat content was influenced by the way they were fed in intensive management, where they would spend much of the time feeding on the supplement feed than scavenging. In past research, Zidane et al.

Table 4: Proximate composition of broiler chicken meat obtained from a genuine supplier and three different markets.

Samples	Proximate composition			
	Moisture content (%)	Ash content (%)	Crude protein (%)	Crude fat (%)
CBC	76.35 ± 0.01^{a}	0.67 ± 0.03^{a}	15.02 ± 0.07^{ab}	16.11 ± 0.29^{a}
MBC 1	76.70 ± 0.01^{a}	0.65 ± 0.02^{a}	14.38 ± 0.07^{c}	15.43 ± 0.09^{b}
MBC 2	75.39 ± 0.02^{a}	0.65 ± 0.05^{a}	15.20 ± 0.15^{a}	15.54 ± 0.07^{b}
MBC 3	75.67 ± 0.02^{a}	0.63 ± 0.02^{a}	14.89 ± 0.07^{b}	15.53 ± 0.14^{b}

Data are mean ± standard deviation. Means ± SD followed by different superscript letters within the same column are significantly different at $p < 0.05$. *Note*. CBC, control broiler chicken; MBC, market broiler chicken.

Table 5: Color composition of broiler chicken meat obtained from a genuine supplier and three different markets.

Samples	Color composition		
	L^*	a^*	b^*
CBC	59.39 ± 0.05^{a}	11.17 ± 0.03^{d}	10.27 ± 0.05^{c}
MBC 1	59.45 ± 0.02^{a}	14.63 ± 0.05^{a}	11.47 ± 0.01^{a}
MBC 2	58.65 ± 0.01^{b}	13.29 ± 0.06^{b}	10.83 ± 0.07^{b}
MBC 3	58.41 ± 0.06^{c}	11.81 ± 0.04^{c}	9.18 ± 0.04^{d}

Data are mean ± standard deviation. Means ± SD followed by different superscript letters within the same column are significantly different at $p < 0.05$. *Note*. CBC, control broiler chicken; MBC, market broiler chicken.

Table 6: Texture profile of broiler chicken meat obtained from a genuine supplier and three different markets.

Samples	Texture profile						
	Adhesiveness (g/sec)	Hardness (g)	Gumminess	Springiness	Cohesiveness	Chewiness	Resilience
CBC	-10.44 ± 0.07^{a}	648.74 ± 45.19^{a}	181.25 ± 9.05^{a}	0.34 ± 0.03^{a}	0.27 ± 0.02^{a}	106.61 ± 4.25^{a}	0.11 ± 0.02^{a}
MBC 1	-10.50 ± 0.14^{a}	626.63 ± 21.00^{a}	167.74 ± 5.44^{a}	0.36 ± 0.01^{a}	0.27 ± 0.01^{a}	107.85 ± 8.94^{a}	0.12 ± 0.04^{a}
MBC 2	-10.48 ± 0.38^{a}	641.01 ± 23.25^{a}	166.79 ± 4.65^{a}	0.32 ± 0.02^{a}	0.26 ± 0.01^{a}	106.02 ± 4.32^{a}	0.10 ± 0.01^{a}
MBC 3	-10.56 ± 0.18^{a}	640.05 ± 30.94^{a}	166.04 ± 11.08^{a}	0.32 ± 0.03^{a}	0.25 ± 0.02^{a}	106.91 ± 3.69^{a}	0.12 ± 0.04^{a}

Data are mean ± standard deviation. Means ± SD followed by different superscript letters within the same column are significantly different at $p < 0.05$. *Note*. CBC, control broiler chicken; MBC, market broiler chicken.

[34] reported that sedentary rearing caused the chicken to become fattier. Besides that, the result of the current analysis is in line with that reported by Okarini et al. [35], who reported that the highest fat content and moisture content were observed in broiler meat possibly due to the different environmental conditions and feeding and rearing systems. A significant difference ($p < 0.05$) between control and market 1 samples was observed in their protein content. The parameter of protein content was slightly similar to control and markets 2 and 3, which indicates that they possessed the same values but market 1 had a slightly low value compared to other chicken samples. This may be due to the fractional rates of protein synthesis and protein degradation that were significantly greater in younger animals than in older ones [35]. Some studies reported that age and species affected the growth rate of the chicken as well as its meat composition. According to Wayan et al. [25], the chemical composition of chicken meat as explained by protein, fat, and moisture of free-range chicken, broiler, and layer chicken meat showed affected by age and rearing systems. Parameters of moisture content and ash content showed no significant difference ($p < 0.05$) between the control and market samples. These indicate that those parameters were not significantly affecting the comparison of control and market samples of broiler chickens.

Table 5 lists the color composition of broiler chicken meat obtained from a genuine supplier and three different markets. There was a significant difference ($p < 0.05$) in the L^*, a^*, and b^* values between control and market samples as market 1 shows a higher value than control and other market samples. The color properties of broiler chicken were due to low heme pigment concentrations because broiler reaches market age at substantially younger ages. Thus, the lack of genetic ability to deposit pigments in the epidermis caused the meat to be lighter and white [36]. This can be supported by a past research work by Saxena et al. [37], who stated that this selection for higher body weight led to lighter meat and attributed to the lower heme-iron content of this broiler meat. A similar finding from Embong et al. [38] mentioned that higher body weight led to certain muscle abnormalities and meat quality defects like pale, soft, and exudative (PSE) as growth hormone allows more substrate to muscle adipose tissue accretion in broiler chickens of four to five weeks of age.

The texture profile is tabulated in Table 6, which showed no significant difference ($p > 0.05$) between control and market samples. From the result, it is evident that broiler chicken is less tough, less gumminess, and less chewy than other breeds due to the high-fat content in broiler chicken meat. High-fat content has been reported to contribute to the reduced meat toughness [18]. Wayan et al. [25] reported that broiler chicken meat has rapid fat depositing capacity and soft texture due to its fast growth rate. Potentially, these parameters are not significantly affecting the comparison between control and market samples of broiler chicken.

Figure 2 illustrates the score scatter plot (PLS-DA component 1 vs PLS-DA component 2), which shows a good clustering of control and market broiler chicken samples. All samples observed were separated into four clusters based on the PCA component 1. Control and market 2 and 3 samples are located on the positive side, while market 1 samples are located on the negative side. The PLS-DA loading column signal corresponding to the clustering is displayed in Supplementary Figure S4. The protein and fat contents were found to be dominant in control and market 2 and 3 samples, while the color properties of L^*, a^*, and b^* values, springiness, cohesiveness, moisture, and ash content were dominant in market 1 samples. Protein is a major component that can be used to differentiate the control and market chicken samples. The protein content is generally affected by the age and growth rate of chickens as the fractional rates of protein synthesis and protein degradation were significantly greater in younger animals than in older ones [35]. Market 1 is, in contrast, to control, market 2 and 3 samples in terms of L^*, a^*, and b^* values. The heme pigment concentrations may have caused the differences as broiler chicken to reach market age substantially at younger ages [36].

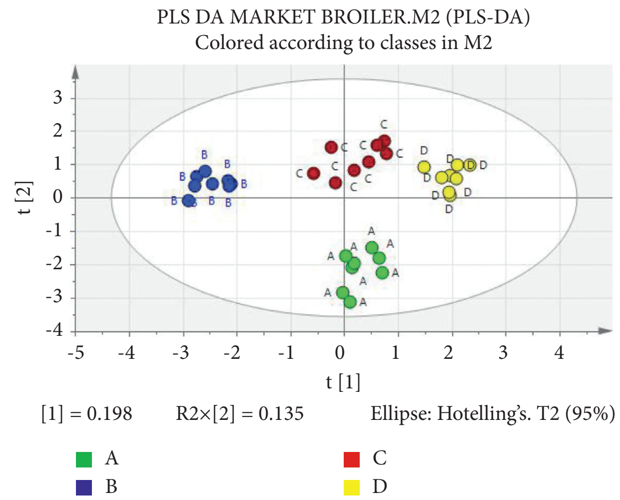

FIGURE 2: The partial least squares-discriminant analysis (PLS-DA) score plot of control and market samples of broiler chicken. Colored circles are represented by CBC = control broiler chicken (green); MBC 1 = market 1 (blue); MBC 2 = market 2 (maroon); MBC 3 = market 3 (yellow).

3.1.3. Colored Chicken. Tables 7–9 summarize the proximate, color, and textural properties of colored chicken meats of the genuine and market samples respectively. The proximate composition of colored chicken meat obtained from a genuine supplier and three different markets are listed in Table 7. A significant difference ($p < 0.05$) in protein and ash content between control and market samples was related to their growth rate and feed consumption. As for their protein content, the control colored chicken (CCC) contributed to a higher value of 17.43% compared to market samples that range from 14.43 to 17.07%. Nobo et al. [39] reported that the growth of chicken was affected by the ability to digest feed that contains crude protein. As the colored chicken is known for its fast growth performance, the protein content can be affected by its growth rate. For ash content, CCC showed a slightly higher value than market samples. According to Chepkemoi et al. [22], the ash content in the feed determines the extent to which dietary minerals would be available in the feed and the rate at which energy in food can be made available.

The fat content of the market 1 samples was similar to the control sample, while markets 2 and 3 showed slightly lower values than the control sample. This was due to the muscles that depend on the energy value of feed given to the chicken and the dietary fat contents of the feeds [40]. A previous study by Embong et al. [38] stated that the fat content in crossbred village chickens was higher compared to purebred village chickens due to the low protein catabolism in the crossbred strain that was used for growth and muscle mass. Meanwhile, there was no significant difference ($p > 0.05$) in the moisture content between control and market samples as it depends on the age of the chicken [21]. Thus, the control and market samples had some similarities in terms of their age at slaughtering.

TABLE 7: Proximate composition of colored chicken meat obtained from a genuine supplier and three different markets.

Samples	Proximate composition			
	Moisture content (%)	Ash content (%)	Crude protein (%)	Crude fat (%)
CCC	71.44 ± 0.01^a	0.97 ± 0.02^a	14.84 ± 0.06^a	8.81 ± 0.10^a
MCC 1	71.42 ± 0.01^a	0.81 ± 0.04^{bc}	12.61 ± 0.15^d	8.72 ± 0.09^a
MCC 2	71.75 ± 0.02^a	0.84 ± 0.03^b	13.38 ± 0.06^c	7.62 ± 0.26^b
MCC 3	70.77 ± 0.02^a	0.74 ± 0.02^c	14.58 ± 0.10^b	7.94 ± 0.51^b

Data are mean ± standard deviation. Means ± SD followed by different superscript letters within the same column are significantly different at $p < 0.05$. *Note.* CCC, control colored chicken; MCC, market colored chicken.

TABLE 8: Color composition of colored chicken meat obtained from a genuine supplier and three different markets.

Samples	Color composition		
	L^*	a^*	b^*
CCC	54.71 ± 0.03^b	12.35 ± 0.06^a	10.47 ± 0.11^b
MCC 1	55.40 ± 0.07^a	11.27 ± 0.12^c	10.30 ± 0.10^b
MCC 2	53.69 ± 0.05^c	10.40 ± 0.07^d	9.73 ± 0.02^c
MCC 3	54.79 ± 0.02^b	11.62 ± 0.07^b	10.69 ± 0.06^a

Data are mean ± standard deviation. Means ± SD followed by different superscript letters within the same column are significantly different at $p < 0.05$. *Note.* CCC, control colored chicken; MCC, market colored chicken.

Table 8 lists the color composition of colored chicken meat obtained from a genuine supplier and three different markets. A significant difference ($p < 0.05$) of color composition between control and market samples was varied from each other due to the amount of myoglobin content in the muscles. According to Ismail and Joo [41], myoglobin,

Table 9: Texture profile of colored chicken meat obtained from a genuine supplier and three different markets.

Samples	Texture profile						
	Adhesiveness (g/sec)	Hardness (g)	Gumminess	Springiness	Cohesiveness	Chewiness	Resilience
CCC	-12.37 ± 0.03^{a}	891.06 ± 27.87^{a}	300.46 ± 22.76^{a}	0.41 ± 0.03^{a}	0.35 ± 0.03^{a}	241.27 ± 57.09^{a}	0.24 ± 0.04^{a}
MCC 1	-12.55 ± 0.20^{a}	880.58 ± 25.43^{a}	302.71 ± 48.08^{a}	0.45 ± 0.02^{a}	0.34 ± 0.04^{a}	234.79 ± 42.40^{a}	0.22 ± 0.01^{a}
MCC 2	-12.32 ± 0.12^{a}	838.05 ± 49.30^{a}	311.25 ± 9.10^{a}	0.42 ± 0.02^{a}	0.33 ± 0.02^{a}	233.27 ± 10.37^{a}	0.27 ± 0.02^{a}
MCC 3	-12.50 ± 0.20^{a}	855.99 ± 34.37^{a}	301.89 ± 1.83^{a}	0.42 ± 0.04^{a}	0.33 ± 0.02^{a}	219.25 ± 8.66^{a}	0.22 ± 0.01^{a}

Data are mean ± standard deviation. Means ± S.D followed by different superscript letters within the same column are significantly different at $p < 0.05$. *Note*. CCC, control colored chicken; MCC, market colored chicken.

which is the sarcoplasmic heme protein contributed to the color of meat, is obtained from a well-bled livestock carcass. The amount of myoglobin depends on the function of myoglobin to store and deliver oxygen to the muscle. Factors such as exercise and diet of the chicken as well as environmental factors can affect the meat color as they were varied based on the species and age [42]. The differences between control and other market samples might also be due to different breeds. Normally, the colored chicken sold in the market was known to be SASSO breed instead of Hubbard.

Table 9 lists the texture profile of colored chicken meat obtained from a genuine supplier and three different markets. All attributes of the texture profile showed no significant difference ($p > 0.05$) between control and market samples. The hardness, gumminess, and chewiness contributed to high values than other attributes due to collagen content in the muscle. The tissue collagen influenced the muscle and bone with significant strength and hard rigid properties. The physical activity of the chicken also contributed to a high amount of connective tissue, thus enhancing the collagen content in the muscles [32]. Other aspects such as protein and fat content can influence the texture properties. The softer texture has resulted from low-fat content and the decrease in protein content affects the mechanical properties of the meats [43].

Figure 3 illustrates the score scatter plot (PLS-DA component 1 vs PLS-DA component 2), which shows a good clustering of control and market colored chicken samples. PCA component 1 separates the clusters into four groups: control and market 1 and 3 samples are located on the positive side, while market 2 samples are located on the negative side. The signals corresponding to the PLS component 1 clustering can be observed in the loading column plot displayed in Supplementary Figure S5. The color attributes of L^*, a^*, and b^* values, followed by fat content, protein content, hardness, ash content, and cohesiveness, were found to be dominant in control and market 1 and 3 samples, while the resilience, adhesiveness, moisture, and gumminess were dominant in market 2 samples. The color properties are strongly associated with the control and market 1 and 3 samples due to the denaturation of sarcoplasmic protein that increased the light scattering and meat paleness. Abdullah and Matarneh [5] also reported that Hubbard chicken had lighter color compared to the Lohmann chicken breed. As in market 2 samples, it is associated with the resilience attribute, which refers to the measurement of how the sample recovers from deformation with speed and force acquired. The loading column plot showed

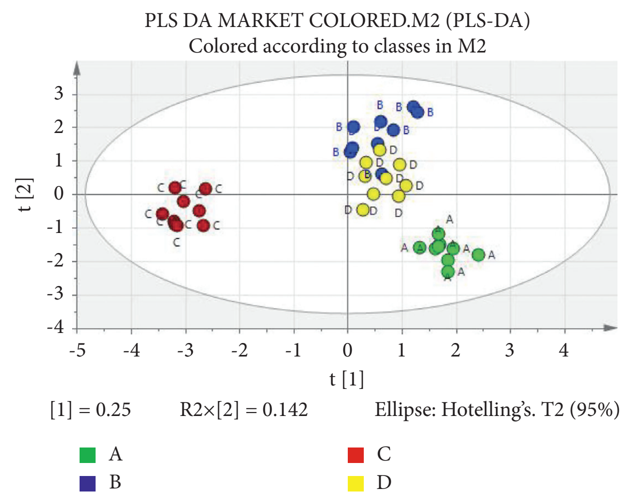

Figure 3: The partial least squares-discriminant analysis (PLS-DA) score plot of control and market samples of colored chicken in terms of proximate, color, and texture properties. Colored circles are represented by A = control colored chicken (green); B = market 1 (blue); C = market 2 (maroon); D = market 3 (yellow).

that markets 1 and 3 were similar in L^*, a^*, b^* values, fat, protein, ash, hardness, and cohesiveness to control samples, while market 2 deviated from other samples in resilience, adhesiveness, moisture, and gumminess.

3.1.4. Layer Chicken. Tables 10–12 summarize the proximate, color, and textural properties of layer chicken meats of genuine and market samples. The proximate composition of layer chicken meat obtained from a genuine supplier and three different markets is listed in Table 10. There was a significant difference ($p < 0.05$) between control and market samples in protein content as the protein content of the control sample was slightly higher (13.25%), which was similar to market 2. Meanwhile, markets 1 and 3 varied from the control sample, which ranged from 11.77% to 12.18% of protein content. This may be due to differences in environmental conditions, feeding, and rearing systems. Previous research by Vaithiyanathan et al. [44] also discovered that the protein composition varied according to the area, where the animals were reared and fed. Parameters such as fat content, moisture content, and ash content had no significant difference ($p > 0.05$) between control and market samples as they possessed similar results to each other. These indicate that those parameters were not significantly

Table 10: Proximate composition of layer chicken meat obtained from a genuine supplier and three different markets.

Samples	Proximate composition			
	Moisture content (%)	Ash content (%)	Crude protein (%)	Crude fat (%)
CLC	72.05 ± 0.01^a	0.63 ± 0.01^a	11.70 ± 0.06^a	7.86 ± 0.34^a
MLC 1	71.39 ± 0.01^a	0.64 ± 0.03^a	10.86 ± 0.15^b	7.85 ± 0.13^a
MLC 2	72.29 ± 0.02^a	0.63 ± 0.02^a	11.60 ± 0.11^a	7.41 ± 0.23^a
MLC 3	72.17 ± 0.01^a	0.65 ± 0.02^a	10.53 ± 0.15^c	7.62 ± 0.33^a

Data are mean ± standard deviation. Means ± SD followed by different superscript letters within the same column are significantly different at $p < 0.05$. *Note*. CLC, control layer chicken; MLC, market layer chicken.

Table 11: Color composition of layer chicken meat obtained from a genuine supplier and three different markets.

Samples	Color composition		
	L^*	a^*	b^*
CLC	52.41 ± 0.09^a	13.31 ± 0.06^b	9.62 ± 0.04^d
MLC 1	51.72 ± 0.05^b	14.65 ± 0.03^a	11.51 ± 0.02^a
MLC 2	51.40 ± 0.06^c	12.72 ± 0.07^c	10.10 ± 0.03^c
MLC 3	51.47 ± 0.11^c	11.81 ± 0.04^d	10.79 ± 0.08^b

Data are mean ± standard deviation. Means ± SD followed by different superscript letters within the same column are significantly different at ($p < 0.05$). *Note*. CLC, control layer chicken; MLC, market layer chicken.

Table 12: Texture profile of layer chicken meat obtained from a genuine supplier and three different markets.

Samples	Texture profile						
	Hardness (g)	Adhesiveness (g/sec)	Springiness	Cohesiveness	Gumminess	Chewiness	Resilience
CLC	1958.01 ± 291.69^a	-14.21 ± 0.05^a	0.46 ± 0.08^a	0.38 ± 0.08^a	728.44 ± 188.28^a	397.25 ± 65.33^a	0.32 ± 0.03^a
MLC 1	1999.02 ± 66.80^a	-14.09 ± 0.20^a	0.49 ± 0.06^a	0.34 ± 0.01^a	680.78 ± 14.84^a	410.00 ± 68.33^a	0.30 ± 0.03^a
MLC 2	1959.89 ± 18.85^a	-14.07 ± 0.19^a	0.45 ± 0.06^a	0.34 ± 0.04^a	671.51 ± 49.16^a	410.87 ± 38.68^a	0.27 ± 0.00^a
MLC 3	1989.00 ± 38.44^a	-14.41 ± 0.45^a	0.47 ± 0.04^a	0.31 ± 0.02^a	631.82 ± 19.72^a	400.03 ± 33.87^a	0.28 ± 0.04^a

Data are mean ± standard deviation. Means ± SD followed by different superscript letters within the same column are significantly different at $p < 0.05$. *Note*. CLC, control layer chicken; MLC, market layer chicken.

affecting the comparison between the control and market samples of layer chicken.

Table 11 lists the color composition of layer chicken meat obtained from a genuine supplier and three different markets. The L^* and b^* values show that there was a significant difference ($p < 0.05$) between control and market samples as the control sample had a high value in lightness compared to other market samples. The layer chicken meat sold in the market usually will be spread on the fire and dipped in aniline solution to ease the removal of feathers, as the older the chicken is, the harder it is to remove the needle feathers by hand. Thus, the L^* and b^* values of the market samples were darker and more yellowish.

Table 12 lists the texture profile of layer chicken meat obtained from a genuine supplier and three different markets. Texture profiles showed no significant difference ($p > 0.05$) between control and market samples. The hardness, gumminess, and chewiness contributed more to the texture of layer chicken, as the age of the chicken affected the meat texture. Layer chickens that did not produce eggs anymore as age increases indicate a high number of connective tissues. Layer chicken or spent hen was related to connective tissue in poultry due to high cross-linking of connective tissue at older ages [45]. It was due to the collagen content that was soft in young birds and rigid in old birds.

Figure 4 illustrates the score scatter plot (PLS-DA component 1 vs PLS-DA component 2), which shows a good clustering of control and market broiler chicken samples. The samples were separated based on the PCA component 1 into four clusters: control samples can be seen located on the positive side, while market 1, 2, and 3 samples are located on the negative side. The PLS-DA loading column plot that displays the signals corresponding to the clustering is illustrated in Supplementary Figure S6. The L^* and a^* values, protein content, fat content, moisture content, resilience, cohesiveness, and gumminess were found to be dominant in control samples, while the b^* values and ash content were dominant in market 1 and 3 samples. All market samples are differing from the control samples due to the different ages at slaughter. Apart from that layer, chicken is reared and fed for their continuous production of eggs, thus the hormone level and metabolism may have contributed to the differences observed in the study.

4. Sensory Evaluation of Control Breeds with Market Chickens

Control breeds were compared with market chickens that are sold at different markets based on sensory evaluation. This section is aimed at how much the similarities of market chickens that are sold at various markets are the same with

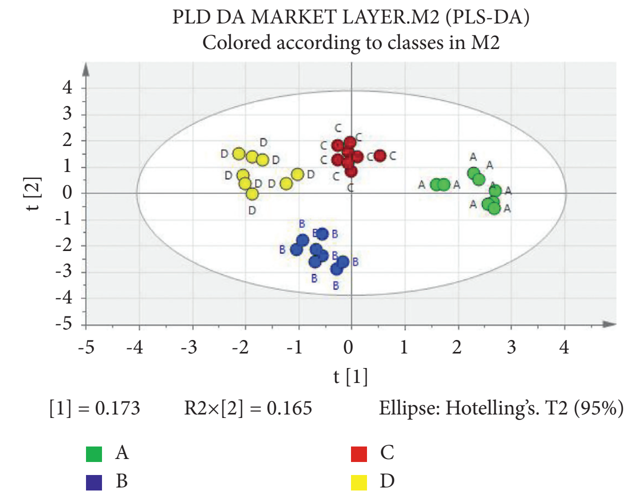

Figure 4: The partial least squares-discriminant analysis (PLS-DA) score plot of control and market samples of layer chicken in terms of proximate, color, and texture properties. Colored circles are represented by CLC = control layer chicken (green); MLC 1 = market 1 (blue); MLC 2 = market 2 (maroon); MLC 3 = market 3 (yellow).

each authentic breed that has been analyzed. All four different breeds of market chickens were bought from a different market to be analyzed using quantitative descriptive analysis (QDA).

4.1. Village Chicken. Based on Table 13, the results between control village chicken (CVC) and market village chicken (MVC) are sold at different markets. Nine different markets have been selected to compare with control village chicken. For the appearance attribute, which is color, all market chickens were shown in the same group as control chickens, which value in between 9.50 ± 1.746 to 11.00 ± 0.685 ($p > 0.05$) except for markets 2 and 9. This is means that majorly all market village chickens were found to have similarities in appearance with slightly dark beige color. Since the value is more than half (>7.50), thus based on Zhuang and Savage [46], previous reports showed 55.4% in color intensity for village chicken. Thus, it proved that the appearance of village chicken significantly stimulates the panelist's appetite by looking at the significant color.

As for the flavor and odor attributes, no significant difference was observed between each market chicken as both show p-value of >0.05 with 0.364 and 0.074, respectively. As Fanatico [47] mentioned, sample preparation can influence the taste and smell of meat. Thus, the odor and flavor for all market chickens were nearly the same with values 12.00 ± 1.261 and 12.00 ± 1.269, respectively. Besides that, the meaty odor and intensity flavor located nearly and almost all markets are distributed surrounding these attributes except markets 2, 8, and 9.

Zhuang and Savage [46] reported that texture is the main contribution for determining the differences between chicken's meat, thus markets 4 and 6 have a significant similarity ($p > 0.05$) with control village chicken in terms of firmness. Markets 2, 6, and 8 share the similarity in firmness attributes. Firmness was obtained from the 1 cm first bite off from incisor teeth; thus, in this study, it was found that majorly not all market has a high hardness to bite 1 cm off from chicken's meat as 66.67% did not match with control chicken's meat.

The following texture attribute is the tenderness that is indirectly proportional to firmness ($p < 0.05$), where firmer meat tends to be potentially chewy. Furthermore, Chumngoen et al. [48] also reported that village chicken meat is less tender compared to broiler chicken meat. Hence, based on this, Table 13 lists that markets 1, 3, 5, 7, and 9 do not have similarities with control chicken's meat.

Both firmness and tenderness also can be influenced by muscle fibers and the juiciness of the meat. Moisture release during the first to the third bite of chicken's meat is the amount of juiciness in chicken's meat. Modlinska and Pisula [49] stated that high crude fat content contributes to greater perceived moisture release. As village chicken is less fat, that is, why the juiciness of village chicken is lower. However, based on markets 4, 5, and 9, they have slightly high juicy content. This may be influenced by the different sizes and weights of chickens as bigger sizes contain high-fat amounts. About 33% of market village chicken is significantly the same as control village chicken as they share the same attributes of texture and appearance with control chicken.

4.2. Broiler Chicken. Table 14 lists the results between control broiler chicken (CBC) and market broiler chicken (MBC) sold at different markets. Figure 5 displays the spider plot corresponding to the results in Table 14. Three different markets have been selected to compare with the control of broiler chicken.

Based on the results obtained, MBC showed no significant difference ($p > 0.05$) with CBC, p = 0.387, 0.069, 0.478, 0.346, and 0.711 for color, flavor, firmness, tenderness, and juiciness attribute, respectively. This means that all chicken markets sold have major similarities with control chicken. According to Modlinska and Pisula [49], broiler chicken has less perimysium and link collagen amount, which results in soft texture after the cooking process. Thus, this can be related to the low firmness amount of broiler chicken, which is 5.00 ± 0.898. As the firmness amount is smaller, the amount of tenderness is high, which is 12.00 ± 0.682. This means that broiler chicken is less chewy.

As for the appearance, broiler chicken appeared to be in bright beige with the value of 12.00 ± 0.826, while the juiciness is also considerably high with 6.50 ± 0.698. Hence, broiler chicken is significantly increasing one's appetite as Spence [50] mentioned that a high amount of juiciness and appearance (bright color) could psychologically be appealing to one's appetite.

4.3. Colored Chicken. Table 15 lists the result between control colored chicken (CCC) and market colored chicken (MCC) sold at three different markets. Based on the graphical representation of the results in Figure 6, only two markets were found; similarly, the same is with control

Table 13: Comparative attributes between control village chickens (CVC) and market village chickens (MVC) sold at a different market.

Samples	Appearance (color)	Intensity flavor	Meaty odor	Firmness	Tenderness	Juiciness
CVC	$9.50^{b} \pm 1.75$	$12.00^{a} \pm 1.26$	$12.00^{ab} \pm 1.27$	$10.00^{a} \pm 0.87$	$5.00^{de} \pm 1.03$	$1.50^{c} \pm 0.34$
MVC 1	$10.50^{ab} \pm 0.93$	$11.50^{a} \pm 2.30$	$10.50^{ab} \pm 1.89$	$7.00^{cde} \pm 1.42$	$10.00^{abc} \pm 1.64$	$3.00^{bc} \pm 1.38$
MVC 2	$12.00^{a} \pm 1.73$	$11.00^{a} \pm 2.67$	$11.00^{ab} \pm 2.78$	$12.00^{a} \pm 1.54$	$4.50^{e} \pm 1.45$	$3.00^{bc} \pm 1.36$
MVC 3	$10.50^{ab} \pm 1.37$	$10.00^{a} \pm 2.10$	$10.00^{ab} \pm 2.30$	$8.00^{cde} \pm 3.35$	$8.00^{cd} \pm 1.82$	$4.50^{a} \pm 2.78$
MVC 4	$11.00^{ab} \pm 0.69$	$8.50^{a} \pm 2.68$	$8.00^{b} \pm 2.35$	$8.50^{bcde} \pm 2.86$	$5.00^{de} \pm 2.11$	$6.00^{ab} \pm 2.20$
MVC 5	$9.50^{ab} \pm 1.40$	$9.00^{a} \pm 2.12$	$11.00^{ab} \pm 1.26$	$5.50^{de} \pm 1.49$	$7.50^{bcd} \pm 2.92$	$5.00^{ab} \pm 2.80$
MVC 6	$10.50^{ab} \pm 0.94$	$9.00^{a} \pm 2.32$	$9.00^{ab} \pm 2.32$	$11.50^{ab} \pm 0.89$	$3.50^{e} \pm 0.90$	$3.00^{abc} \pm 1.10$
MVC 7	$10.00^{ab} \pm 2.47$	$11.50^{a} \pm 1.61$	$12.50^{a} \pm 1.73$	$6.50^{e} \pm 2.87$	$12.50^{a} \pm 2.14$	$2.50^{abc} \pm 1.29$
MVC 8	$10.00^{ab} \pm 1.03$	$11.00^{a} \pm 1.18$	$11.50^{ab} \pm 1.23$	$9.50^{abcd} \pm 0.83$	$7.50^{cd} \pm 0.78$	$3.00^{bc} \pm 0.58$
MVC 9	$4.50^{c} \pm 1.66$	$9.00^{a} \pm 2.36$	$11.00^{ab} \pm 2.44$	$7.50^{cde} \pm 2.55$	$10.00^{ab} \pm 1.41$	$5.00^{ab} \pm 1.53$

CVC, control village chicken; MVC, market village chicken. ^{*abcde}Mean values with different superscripts between the columns are significantly different ($p < 0.05$). Data are expressed as mean ± SD

Table 14: Comparative attributes between control broiler chicken (CBC) and market broiler chicken (MBC) sold at the market.

Samples	Appearance	Intensity flavor	Meaty odor	Firmness	Tenderness	Juiciness
CBC	$12.00^{a} \pm 0.94$	$10.00^{a} \pm 1.12$	$10.00^{a} \pm 1.08$	$6.00^{a} \pm 1.38$	$11.50^{a} \pm 1.00$	$6.50^{a} \pm 0.82$
MBC 1	$11.75^{a} \pm 0.79$	$9.25^{a} \pm 0.81$	$9.00^{ab} \pm 0.84$	$5.00^{a} \pm 1.10$	$11.50^{a} \pm 0.66$	$6.50^{a} \pm 0.70$
MBC 2	$12.00^{a} \pm 0.83$	$8.85^{a} \pm 0.47$	$8.50^{b} \pm 0.35$	$5.00^{a} \pm 0.90$	$12.00^{a} \pm 0.68$	$6.50^{a} \pm 0.85$
MBC 3	$11.75^{a} \pm 0.87$	$8.75^{a} \pm 0.76$	$8.50^{ab} \pm 0.68$	$5.00^{a} \pm 0.97$	$11.75^{a} \pm 0.62$	$7.00^{a} \pm 0.74$

CBC, control-broiler chicken; MBC, market broiler chicken. ^{*ab}The mean values with different superscripts between the columns are significantly different ($p < 0.05$). Data are expressed as mean ± SD

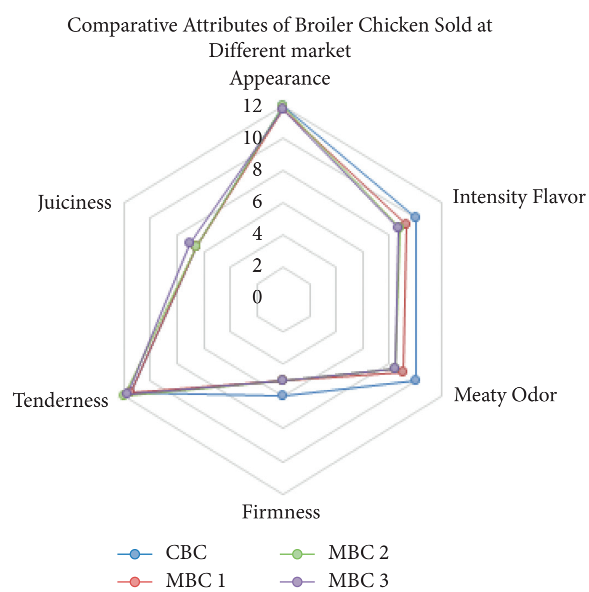

Figure 5: Spider plot of comparative attributes of broiler chicken sold at different markets. CBC, control broiler chicken; MBC, market broiler chicken.

Table 15: Comparative attributes between control colored chicken (CCC) and market colored chicken (MCC) sold at the market.

Samples	Appearance	Intensity flavor	Meaty odor	Firmness	Tenderness	Juiciness
CCC	$9.50^{b} \pm 1.49$	$10.50^{a} \pm 0.71$	$11.00^{b} \pm 0.97$	$6.00^{a} \pm 0.99$	$10.50^{a} \pm 1.03$	$2.50^{b} \pm 0.63$
MCC 1	$9.50^{b} \pm 1.16$	$8.00^{b} \pm 1.08$	$7.50^{a} \pm 0.85$	$5.00^{a} \pm 0.96$	$11.00^{a} \pm 0.80$	$6.50^{a} \pm 0.86$
MCC 2	$11.50^{a} \pm 1.47$	$10.50^{a} \pm 0.98$	$12.00^{a} \pm 1.55$	$5.00^{a} \pm 1.02$	$9.50^{a} \pm 1.33$	$2.50^{b} \pm 0.86$
MCC 3	$10.50^{ab} \pm 0.94$	$10.50^{a} \pm 0.71$	$11.00^{a} \pm 0.95$	$6.00^{a} \pm 0.76$	$11.00^{a} \pm 0.79$	$2.50^{b} \pm 0.59$

CCC, control colored chicken; MCC, market colored chicken. ^{*ab}The mean values with different superscripts between the columns are significantly different ($p < 0.05$). Data are expressed as mean ± SD

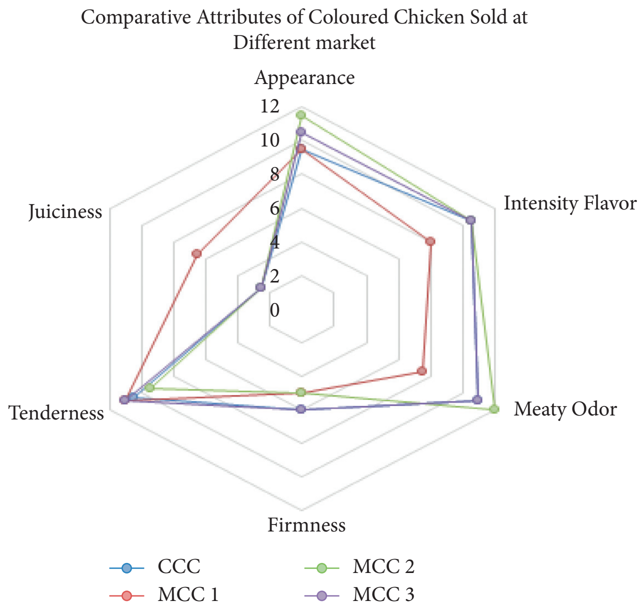

Figure 6: Spider plot of comparative attributes of colored chicken sold at different markets. CCC, control colored chicken; MCC, market colored chicken.

except for market 1 ($p < 0.05$). The differences may be due to some factors such as duration during sample preparation. Probably due to the market, samples were cooked at the same time but were not cut simultaneously after cooling for five minutes. Thus, the odor of layer chicken was evaporated. As National Research Council [51] reported that smell could influence the flavor, which may contribute to the low intensity of flavor and odor in market 1.

Reportedly, about 66% of market layer chicken is significantly the same as control layer chicken as they share the same attributes of intense flavor and meaty odor. Meanwhile, firmness, tenderness, and appearance showed significant differences between the control and market colored chicken. Although Zhuang and Savage [46] reported that texture is the main contribution to determine the differences between chicken meats, market 1 cannot be considered the same with control even though the results displayed firmness and tenderness have similarities with control.

4.4. Layer Chicken. Table 16 lists the results between control layer chicken (CLC) and market layer chicken (MLC) sold at three different markets. The spider plot in Figure 7 was illustrated based on the results tabulated (Table 16), to display the differences between each market with control chicken. The juiciness showed a low amount in each market with values ranging from 1.00 ± 0.157 to 1.50 ± 0.354 ($p < 0.05$). These results can be related to the amount of fat content in layer chickens, according to a book titled Nutrients Requirements of Poultry by the Xing et al. [52] stated that hens eat less feed with increasing temperature, especially above 30°C, as layer chickens need to save their energy for egg production. Besides, Wideman et al. [53] reported that excessive fat accumulation in layer chickens could negatively affect their egg production.

For appearance attributes, all market samples do not stay in the same group with control layer chicken (CLC). This is because, during slaughtering of CLC, the chicken carcass was not soaked in hot water and not smoked on fire. Meanwhile, for market layer chicken (MLC), the skin was being smoked with fire before selling to the customer (markets 1 and 3). The seller mentioned that some layer of chicken's feather was hard to detach, thus with the burning of the chicken's skin, consumers can easily clean the chicken to be cooked. However, for market 2, they were not "burn" the chicken's skin as requested, but the color intensity was still high compared with the control layer chicken. This may be caused by age factor, storage time, or environmental factors. As Siekmann et al. [54] stated that slaughtering older chickens causes increased myoglobin and heme pigment amount which can result in the dark color of chicken's skin, thus indicating age as a contributing factor. This majorly affects panelists to describe the appearance attribute of layer chickens. Due to the reasons, market layer chickens were more attractive and stimulating to the panelists' appetite with the smoky effect.

Xie, et al. [55] reported that the intensity of meaty odor increases with increasing chicken age. However, in this study, the control sample showed a low odor value (9.00 ± 1.581) compared to the other market samples. This is because the temperature will affect the odor as it increases molecular volatility. According to Damaziak et al. [56], the volatile acids, alcohols, and esters were dominant in chicken breast meat, which may have contributed to the odor value for markets 1 and 3, which is potentially high. As for tenderness, market 2 displayed the same value as of control, which is 4.00 ± 1.972 ($p > 0.05$). Meanwhile, the other two markets were distinctly different from control, which is related to the various ages between control chicken and market chicken. About 33% of market layer chicken is significantly the same as control layer chicken as they share the same attributes of firmness.

Overall, the results indicate that markets 2 and 4 that supply the village chicken were found to be more of the genuine characteristics based on the protein and fat content measured upon comparison with the control village chicken. The others may have the village chicken grown in a different environment and fed with different formulations instead of the free-range system. The textural features of these 2 markets are comparable to those of the control, especially the hardness and chewiness. Probably, the rest of the market supplies village chicken with formulated feed and in an indoor system; perhaps, the authenticity is considerably not taken into account. In general, the sense of appearance as indicated via color is one of the most important quality attributes of poultry meat among consumers since the color is often associated with products' freshness and it is chosen based on its attractiveness [36]. This indicates that visual assessment is one of the criteria in sensory evaluation; however, a true assessment of sensory attributes shall include odor, tenderness, and juiciness that eventually give good taste [57]. Broiler chickens of control and market supply were found to be juicier compared to all other breeds. Notably, the fat content in the broiler chicken meat as well as

Table 16: Comparative attributes between control layer chicken (CLC) and market layer chicken (MLC) sold at the market.

Samples	Appearance (color)	Intensity flavor	Meaty odor	Firmness	Tenderness	Juiciness
CLC	$7.50^{a} \pm 1.34$	$8.50^{a} \pm 1.46$	$9.00^{ab} \pm 1.58$	$11.50^{a} \pm 0.81$	$3.50^{a} \pm 0.76$	$1.50^{a} \pm 0.85$
MLC 1	$10.50^{b} \pm 1.92$	$13.00^{b} \pm 2.58$	$13.00^{bc} \pm 3.00$	$9.50^{a} \pm 1.93$	$6.50^{bc} \pm 1.41$	$1.00^{b} \pm 0.16$
MLC 2	$10.00^{b} \pm 1.73$	$11.50^{ab} \pm 1.98$	$8.50^{ab} \pm 1.89$	$9.50^{a} \pm 2.19$	$4.00^{ab} \pm 1.97$	$1.00^{b} \pm 0.31$
MLC 3	$12.00^{b} \pm 1.92$	$13.50^{b} \pm 0.97$	$13.00^{c} \pm 1.64$	$8.00^{b} \pm 1.00$	$8.00^{c} \pm 1.73$	$1.50^{ab} \pm 0.35$

CLC, control layer chicken; MLC, market layer chicken. ^{*ab} The mean values with different superscripts between the columns are significantly different ($p < 0.05$). Data are expressed as mean ± SD.

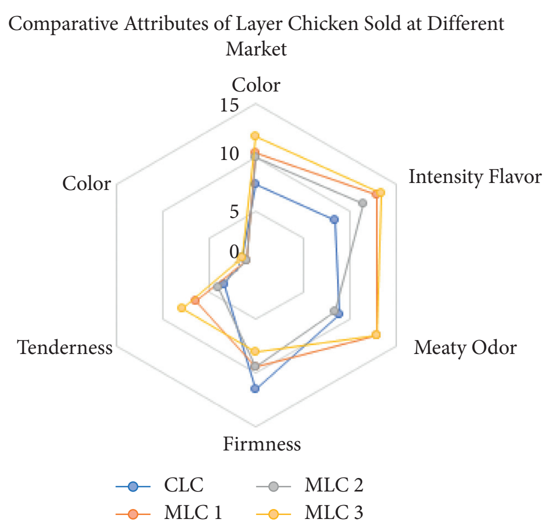

Figure 7: Spider plot of comparative attributes of layer chicken sold at a different market. CLC, control layer chicken; MLC, market layer chicken.

the water cooking method contributes to its juiciness [56–58]. Juiciness is comparably high in male chickens due to caponization that leads to the accumulation of intramuscular fat and to improve the lipid profile of meat, which makes the meat tenderer, juicier, and tastier [57]. However, layer chicken of control and market supply meat was less juicy than others. All these features should be considered as crucial authentication criteria that may help to combat food fraud in the poultry industry, despite being minor or major implications.

5. Conclusions

This research has shown that there were observable significant differences ($p < 0.05$) between all chicken breeds in terms of proximate composition, color composition, and textural properties. The texture attributes of chewiness, hardness, gumminess, cohesiveness, resilience, and springiness, followed by protein, ash content, and $^{*}a$ and b^{*} values were found to be good indicators to distinguish the village chicken samples from other chicken breeds. Meanwhile, adhesiveness, fat content, L^{*} value, and moisture content could be a good indicator to differentiate between broiler chickens, followed by colored and layer chicken. The second objective showed that 80% of the village chicken meats obtained from local markets were not true village chicken meats. Meanwhile, one of the colored and broiler market samples was different from the control and other market chicken samples. For layer chicken, all market samples differed from control samples. Hence, the comparison of different chicken breeds obtained from genuine suppliers with chicken breeds sold in different local markets can be differentiated. All characteristics analyzed can be applied as a guideline to generate standard protocols in the authentication process by the local authority and educate and create awareness among the consumers.

Data Availability

Data are available on request from the corresponding author.

Ethical Approval

The ethical approval was issued by the Institutional Animal Care and Use Committee (IACUC) at Universiti Putra Malaysia with reference number UPM/IACUC/AUP-R023/2020.

Consent

The participation of the panelists in the sensory analysis was based on voluntarism.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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Supplementary Materials

Tables S1 and S2 in the Supplementary Material list the suppliers' and markets' information. Figures S1 and S2 in the Supplementary Material show images of meat samples and color analysis. Figures S3–S6 in the Supplementary Material show the loading plot generated from the PLS-DA model. (*Supplementary Materials*)

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