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Environmental Enrichment Has Minimal Impact on Fresh and Processed Meat Quality of Turkeys

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Abstract: The objective of this study was to determine impacts of environmental enrichment (EE) on turkey meat quality. A randomized complete block design was used with commercial turkeys ($n = 420$) randomly assigned to 6 EE treatments (control [C], pecking block [PB], platform [P], wooden platform + straw bale [PSB], straw bale [SB], and tunnel [T]) across 24 pens (16 to 18 turkeys/pen). At 19 wk, turkeys were weighed (live weight [LW]), and 6 birds per pen were harvested, a subset ($n = 96$ carcasses) fabricated into wings, drumsticks, and boneless breasts and thighs. From the breast and thigh, samples were taken for pH and drip loss. From the breast, samples were taken for instrumental color and shear force, with remaining breast portions further processed into boneless turkey breast logs. From each log, slices were taken for packaged purge loss (PPL), expressed moisture loss (EML), instrumental color, and texture. All EE treatments were analyzed using PROC GLM. For LW, SB turkeys were lightest, PB turkeys were heaviest, and T, PSB, C, and P were intermediate ($P = 0.01$). For fresh turkey, EE treatment did not impact the fabrication values, fresh breast color, breast or thigh drip loss, or breast or thigh pH ($P > 0.05$) and had minimal impact to thigh color with significant differences only in the b^* values ($P = 0.04$). For processed turkey, EE did not impact processing yield, PPL, a^*, b^*, or texture ($P > 0.05$). For L^*, SB, T, P, and PSB were lighter, C were darker, and PB had intermediate values ($P = 0.02$). PB, PSB, C, and T had greater EML loss, P had the least, and SB had intermediate EML ($P = 0.04$). The results indicate some variations of turkey quality due to EE, but the impacts of specific enrichments were not consistent across quality parameters.

Key words: turkey, environmental enrichment, fresh meat quality, processed meat quality
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Introduction

Over the past several years, intensive housing and selective breeding have made it possible to produce heavier poultry in a shorter period of time (Rémigon, 2004; Clark et al., 2019). However, this rapid rate in growth sometimes comes at the cost of losing the ability to perform natural behaviors and may have led to various muscle abnormalities (Zampiga et al., 2019, 2020). As a result, consumers have been increasingly concerned about animal welfare, the number of animal welfare certification programs has increased, and more turkeys are being produced for niche markets (Troy and Kerry, 2010; Erasmus, 2018).

Environmental enrichment (EE) is a possible solution to address the negative impacts of intensive housing and improve animal welfare. Sherwin et al. (1999) discovered that access to enrichments, such plywood boards with chains attached or supplemental ultraviolet radiation, can reduce the incidence of injuries caused by wing or tail pecking among male turkeys. Martrenchar et al. (2001) confirmed that access to bales of straw, metal objects, and wood perches resulted in turkeys that displayed fewer pecking-related injuries. Silva et al. (2021) discovered that broiler chickens with EE were calmer when faced with human presence and touch compared to broiler chickens without EE. In addition to reduced

expression of fear, access to EE increased locomotion with broilers exhibiting greater exploratory activity, while chickens with no EE were less active (Silva et al., 2021). Moreover, EE can be introduced to lower footpad dermatitis scores and improve growth rates in broilers (Spieß et al., 2022). Finally, Akşit et al. (2017) determined perch treatments had no impact on breast muscle pH but increased instrumental color yellowness and redness values of broiler chickens.

Although the effects of EE on animal welfare have been studied within various avian species, there is very limited information about the effects of EE on fresh or processed meat quality, particularly in turkey. This study attempted to fill the knowledge gap by examining the effect of EE on fresh and processed meat quality of turkeys, with the hypothesis being that EE would positively impact animal welfare to the point of improving fresh and processed meat quality attributes.

Materials and Methods

Environmental enrichment

The study was conducted at the Purdue University Poultry Research Unit in West Lafayette, Indiana, from February to June 2021. The Purdue Animal Care and Use Committee approved all experimental methods and procedures. Nicholas Select beak-trimmed male turkeys ($n = 420$) were obtained from a commercial hatchery at 1 day old and housed at Purdue University's Animal Sciences Research and Education Center (West Lafayette, IN). The turkeys were initially raised in brooding rings; then, at 12 d of age, turkeys were randomly assigned to 6 enrichment treatments: no EE (control; C), pecking block (PB), wooden platform (P), straw bale (SB), wooden platform + straw bale (PSB), and plastic tunnel (T).

PB pens had one rectangular PB (0.23 m × 0.23 m × 0.18 m), with blocks replaced as they were destroyed. P pens has one wooden platform (0.99 m × 0.61 m) with 2 ramps (1.22 m × 0.61 m) that were at a 30-degree angle relative to the ground, with wooden strips 6 cm apart. SB pens had one SB (1.02 m × 0.51 m × 0.30 m), with bales replaced when the top collapsed and turkeys were no longer able to stand. PSB pens had one platform identical to P pens and one SB identical to SB pens. T pens had one tunnel (0.61 m × 0.61 m × 0.58 m) made of corrugated plastic sheets attached to a wooden frame. Example images of each treatment were published in Dong et al. (2023).

Each treatment was replicated within 2 barns, with 24 pens total ($n = 4$ pens/treatment). The turkeys were housed in groups of 16 to 18 birds/pen with a stocking density of 2.15 to 2.42 birds/m^2. Each littered (wood shavings) pen measuring 3.05 m by 2.44 m contained one feeder and 2 bell drinkers. Turkeys were fed a standard commercial feed, and both feed and water were provided ad libitum. Lighting and temperature were maintained according to standard industry practices. For lighting, turkeys were initially provided with 24 h of light and then gradually adjusted to 16 h light and 8 h dark by day 4. For temperature, turkeys were initially kept at 30°C for brooding, and then temperature was gradually decreased to 13°C by week 14.

Harvest and fresh meat sampling

At 19 wk of age, the 6 turkeys that weighed closest to the pen average live weight (LW) were chosen from each pen for a total of 144 turkeys designated for harvest. Turkeys were divided into 2 harvest days (3 birds per pen per day) and killed 48 h apart at Purdue University's Land O'Lakes Center for Experiential Learning (West Lafayette, IN). Turkeys were electrically stunned, exsanguinated, scalded, and plucked individually, with identification maintained through the process. Carcasses were weighed (hot carcass weight [HCW]) to determine dressing percentage (DP), and all carcasses were placed on racks and air chilled for 24 h in refrigeration (4°C) to maintain consistent chilling environments prior to further processing. DP was calculated using the following formula:

$$\%DP = (HCW/LW) \times 100$$

A subset of 96 carcasses (2 carcasses randomly selected per pen per day) were used for determining carcass cutting yields (CY) and fresh and processed meat quality. At 24 h postmortem, carcasses were fabricated into legs, wings, boneless thighs, and boneless breasts, with weights recorded for each portion and CY for each cut calculated as a percentage of the HCW using the following formula:

$$\%CY = (portion\ weight/HCW) \times 100$$

From one breast, two 1.25-cm-thick portions were removed beginning from the posterior end of the breast for pH and drip loss (DL). The pH samples were immediately vacuum-packaged and stored in a freezer (−40°C), while the DL samples were further analyzed. From the anterior end of the same breast, two 2.54-cm-thick slices were taken for Warner-Bratzler shear force

and instrumental color analysis. After instrumental color analysis, samples were vacuum-packaged and frozen (−40°C). All remaining breast meat from each carcass was pooled, packaged, and stored in refrigeration (4°C) until further processing.

For thigh fabrication, two 1.25-cm-thick slices were taken from the center portion of one thigh for pH and DL. The pH samples were analyzed for instrumental color then packaged and stored in a freezer (−40°C) until further analysis.

pH measurements

Fresh breast and thigh pH was determined using the procedure by Rathgeber et al. (1999) with minor modifications. After the samples were thawed, 3 g of samples was added to 27 mL of distilled deionized water in duplicate. The samples were homogenized for 10 to 15 s (IKA T 25 digital ULTRA TURRAX) at 12,000 rpm, and the samples were filtered through Whatman No. 1 filter paper. Each filtered sample was measured for pH using a pH probe (Sartorius PB-11, Gottingen) calibrated to pH standards of 4.0, 7.0, and 10.0. Final pH was averaged between the duplicates.

Fresh meat drip loss

DL of fresh samples was measured according to Honikel (1998). Both fresh breast and thigh turkey samples were cut from the carcass and weighed (drip initial weight). Breast samples were 1.25-cm-thick portions removed beginning from the posterior end of one breast, with initial weights of approximately 60 g. Thigh samples were 1.25-cm-thick slices taken from the center portion of one thigh, with initial weights of approximately 70 g. The samples were then suspended within a Whirl-Pak bag and hung at refrigerated temperatures (4°C) for 24 h. After 24 h, the samples were gently blotted dry and weighed again (drip final weight). DL is expressed as a percentage of the initial weight and was calculated using the following equation:

$$\%DL = ((drip\ initial\ weight - drip\ final\ weight)/ drip\ initial\ weight) \times 100$$

Processed meat samples

All breast tissue that remained after the fresh meat sampling was packaged and stored in refrigeration (4°C) for 5 d until further processing. A commercial brine solution was produced with 226.8 g of Legg's Ham Brine (salt, brown sugar, sodium phosphate, sodium erythorbate; A.C. Legg, Inc., AL), 30.28 L of water, and 181.6 g of Legg's cure (6.25% sodium nitrite). All turkey breast samples were trimmed to remove excess fat and connective tissue and then knife-texturized to increase surface area. Fresh breasts were weighed and pumped with commercial brine to 110% by weight. Brined breast was then vacuum-sealed under 661.2 mm Hg (Promax Vac., DC800-FB Vacuum Chamber, 2019) and vacuum-tumbled (Lance Industries, LT-30) at 9 rpm for 90 min, stopping every 15 min for 10 min (Daigle et al., 2005). Tumbled breasts were stuffed into cellulose casings and clipped tightly to produce boneless turkey logs. After 24 h, the boneless turkey logs were weighed (initial processed weight), placed into a smokehouse (ScottPec Inc., Scott Mini Smokehouse, 01E-Mini, 2017), and thermally processed (internal temperature 68.3°C). After thermal processing, the turkey breast logs were stored in refrigeration (4°C) for 96 h before being weighed again (final processed weight) and sliced.

Processing yield was expressed as a percentage of the initial processed weight and was calculated using the following equation:

$$\%PY = (final\ processed\ weight / initial\ processed\ weight) \times 100$$

From each log, four 1.25-cm-thick slices were taken for packaged purge loss (PPL), expressed moisture loss (EML), and texture profile analysis. The PPL samples were analyzed for instrumental color before further analysis. The EML and texture samples were packaged in plastic bags and stored in refrigeration (4°C) for 24 h before proceeding to analysis.

Instrumental color

Instrumental color measurements were taken on fresh breast, fresh thigh samples, and processed boneless turkey slices. Commission Internationale de l'Eclairage (CIE) L^*, a^*, and b^* values were obtained using a Minolta CR-400 (8 mm aperture, 2° observer, illuminant D65), collected in triplicate, and averaged to calculate the mean L^*, a^*, and b^* values for each sample.

Fresh breast cook loss and Warner-Bratzler shear force

Cook loss (CL) was measured according to the Honikel (1998) CL procedure. Frozen breast samples were thawed in refrigeration (4°C) 24 h before cooking. Each breast was weighed individually (fresh initial weight). Samples were placed in plastic bags with

thermometers inserted into the geometric center and placed in a continuously hot water bath (80°C). The samples were cooked until the internal temperature reached 71°C. Once the samples were cooked, the samples were removed from the water bath and placed in refrigeration (4°C). Samples were chilled for 24 h before being gently blotted dry and weighed (final cooked weight). CL is expressed as a percentage of the initial weight and was calculated using the following equation:

$$\%CL = ((fresh\ initial\ weight - final\ cooked\ weight)/ fresh\ initial\ weight) \times 100$$

For Warner-Bratzler shear force (WBSF) six, 1 cm × 1 cm slices were cut from each cooked breast sample parallel to the muscle fiber direction. Each slice was then sheared perpendicular to the muscle fiber direction using a TA-XT Plus Texture Analyzer (Stable Micro System Ltd., UK) with the Warner-Bratzler shear attachment. The test speed was set at 2 mm/s, and the peak shear force (kg) was recorded and averaged for the sample.

Packaged purge loss

After instrumental color measurements were taken on the PPL samples, the samples were weighed (purge initial weight). The samples were then vacuum-sealed (Promax Vac., DC800-FB Vacuum Chamber, 2019) under 30% vacuum individually and placed in refrigeration (4°C) for 24 h. After storage, samples were gently blotted dry and weighed again (purge final weight). Purge loss is expressed as a percentage of the initial weight and was calculated using the following equation:

$$\%PL = ((purge\ initial\ weight - purge\ final\ weight)/ purge\ initial\ weight) \times 100$$

Processed meat instrumental texture profile analysis

Instrumental texture profile analysis of the further processed, boneless turkey breast samples, was determined using a procedure similar to Bower et al. (2018). Two 1.25-cm slices were removed, and a 4 × 4 cm square was cut from the center of each slice. The 2 squares were analyzed by a TA-XT Plus Texture Analyzer (Stable Micro System Ltd., UK) using a TA-25 cylindrical probe to measure hardness, cohesiveness, and springiness. The 2 squares were compressed twice to 75% of the original thickness with a crosshead speed of 30 mm/s, and the results were averaged to calculate the mean hardness, cohesiveness, and springiness values for each sample.

Expressed moisture loss

EML of the further-processed boneless turkey breast samples was determined using a similar procedure to Daigle et al. (2005). One 1.25-cm slice was used to obtain four 1.9-cm-diameter cores. Each core was weighed initially (core initial weight) and placed between 2 pieces of Whatman No. 1 filter paper. Each core was analyzed by a TA-XT Plus Texture Analyzer (Stable Micro System Ltd., UK) using a TA-25 cylindrical probe. Each core was compressed to 75% of the original thickness with a crosshead speed of 10 mm/s and held for 15 s. Each core was then weighed again (core final weight). Expressed moisture is stated as a percentage of the core initial weight and was calculated using the following equation:

$$\%EML = ((core\ initial\ weight - core\ final\ weight)/ core\ initial\ weight) \times 100$$

The results of the 4 cores were then averaged to calculate the mean EML for each sample.

Statistical analysis

This study utilized a randomized complete block design, with 6 EE treatments and 4 replications, blocked by barn. Harvest day and barn were considered random effects. Each pen was represented by 6 turkeys that were closet to the pen average for LW for weights and DP, and then 2 carcasses were randomly selected for fresh and processed meat quality. For CL and WBSF, peak end-point temperature was used as a covariate. All treatment levels were analyzed using PROC GLM of SAS (9.4, SAS Institute, Cary, NC) with statistical significance level set at $P \leq 0.05$.

Results and Discussion

In order to evaluate the impact of EE on turkey meat quality, a control (no EE) and 5 treatments were selected with the intention to improve animal welfare attributes for commercial turkeys that could positively impact meat quality. The EE treatments of wooden platforms (P) and plastic tunnels (T) were chosen to impact feather quality, feather cleanliness, and walking ability. SB and PB were chosen to satisfy pecking and foraging needs. While an EE of wooden platforms

and straw bales (PSB) served as combination treatment. Animal welfare indicators such as turkey activity, locomotion, footpad dermatitis, feather quality, and feather cleanliness were evaluated and reported in Dong et al. (2023). These findings determined that EE treatments can be used to improve animal welfare measurements and activities. For this study, both fresh and processed meat quality attributes were quantified to gain an understanding of EE to final product characteristics.

Fresh meat carcass and quality traits

The LW, HCW, DP, CY, DL (breast and thigh), pH (breast and thigh), WBSF, and CL data are shown in Table 1. For LW, it was found that PB turkeys were the heaviest (17.17 kg), SB turkeys were the lightest LW (16.05 kg), and T, PSB, C, and P were intermediate ($P = 0.01$). Although HCW was not significantly impacted by EE treatment ($P = 0.13$), HCW results did follow a similar trend to LW values, as SB turkeys had the lowest HCW. Furthermore, for DP, it was found that PSB, SB, and T turkeys demonstrated the greatest DP, while PB turkeys had the lowest DP, and C and P were intermediate ($P = 0.02$).

These results were contradictory to other studies that noticed broilers without EE presented the highest LW due to decreased locomotion (Jacob et al., 2020; Silva et al., 2021). DP is calculated using LW and hot carcass weight (HCW), so if either HCW or LW is impacted by treatment, it is expected that DP would likely also be impacted. DP can be influenced by sex, diet, gut fill, dirt, fat, muscle, etc. (Boler, 2014). Since the turkeys were all male, fed the same diet, and weighed at the same time in relation to feeding, these traits did not cause the LW and DP differences among treatments. The fat and muscle composition of the turkey carcasses can also be removed as a source of variation, as HCW was not impacted by EE treatment. Therefore, the PB turkeys may have had feathers that contained a greater amount of dirt or manure, resulting in the greatest LW and least DP. This inference is supported by the results from Dong et al. (2023) that showed turkeys with a PB enrichment contained dirtier breast and belly feathers compared to turkeys with P, T, and SB enrichments. A greater amount of dirt or manure accumulated on feathers could also indicate reduced locomotion. In future studies, to determine if dirty feathers are responsible for a greater LW and reduced DP, evaluations of bird cleanliness would need to be determined.

For carcass CY, as expected, all of the EE treatments followed a similar pattern for the portion cuts, with breasts accounting for the majority of the CY, followed by thighs, legs, and wings. However, EE treatment did not impact the carcass CY values for any of the portion cuts (Table 2; $P > 0.05$). Since

Table 1. Effect of environmental enrichment on carcass and fresh meat quality traits of turkeys

	Environmental Enrichment[1]							
Trait[2]	C	P	PB	PSB	SB	T	SEM	*P* Value
LW (kg)	16.61^{ab}	16.44^{bc}	17.14^{a}	16.67^{ab}	16.05^{c}	16.75^{ab}	0.20	0.01
HCW (kg)	14.36	14.23	14.54	14.63	14.06	14.57	0.17	0.13
DP (%)[2]	86.42^{ab}	86.68^{ab}	84.99^{b}	87.79^{a}	87.59^{a}	87.04^{a}	0.61	0.02
Breast CY (%)	29.58	28.43	28.61	29.22	27.67	28.98	0.65	0.39
Thigh CY (%)	15.44	15.28	15.42	15.35	15.53	15.24	0.30	0.99
Wing CY (%)	10.65	10.85	10.71	10.55	11.07	10.43	0.19	0.21
Leg CY (%)	13.57	13.66	13.44	13.42	13.37	13.17	0.19	0.58
Breast pH	5.80	5.75	5.84	5.82	5.80	5.79	0.02	0.20
Thigh pH	6.00	6.01	6.05	6.06	6.06	6.01	0.03	0.39
Breast DL (%)	0.47	0.46	0.39	0.39	0.61	0.47	0.11	0.77
Thigh DL (%)	0.22	0.21	0.20	0.18	0.17	0.17	0.04	0.93
WBSF (kg)	1.96	1.93	1.81	1.81	1.79	1.78	0.07	0.23
CL (%)	17.83	17.37	15.95	18.79	17.38	16.98	0.80	0.21

[1]C = control (no environmental enrichment); P = wooden platform; PB = pecking block; PSB = wooden platform + straw bale; SB = straw bale; SEM = standard error of the mean; T = plastic tunnel.

[2]LW = live weight; HCW = hot carcass weight; DP = (HCW/LW) × 100; CY = (portion weight/HCW) × 100; DL = ([drip initial weight – drip final weight]/drip initial weight) × 100; WBSF = Warner-Bratzler shear force of fresh breast samples; CL = cooking loss of fresh breast samples ([(fresh initial weight – final cooked weight)/(fresh initial weight)] × 100).

[a–c]Means lacking a common superscript difference due to the main effect of environmental enrichment ($P < 0.05$).

Table 2. Effect of environmental enrichment on instrumental color (CIE L^* [lightness], a^* [redness], and b^* [yellowness]) for fresh breast, fresh thigh, and processed turkey breast

		Environmental Enrichment[1]							
Sample	Color	C	P	PB	PSB	SB	T	SEM	*P* Value
Fresh Breast	L^*	44.88	44.89	44.78	45.51	44.43	45.21	0.53	0.78
	a^*	5.90	5.70	5.69	5.86	5.41	5.97	0.18	0.25
	b^*	2.21	2.24	2.18	2.54	2.11	2.53	0.17	0.37
Fresh Thigh	L^*	43.18	42.93	42.94	42.75	42.70	42.58	0.43	0.94
	a^*	12.00	12.44	11.85	13.11	12.14	12.68	0.33	0.07
	b^*	5.45^{abc}	5.66^{ab}	5.09^{c}	5.99^{a}	5.27^{bc}	5.39^{bc}	0.20	0.04
Processed Turkey Breast	L^*	72.69^{b}	73.98^{a}	73.52^{ab}	73.60^{a}	74.14^{a}	74.01^{a}	0.32	0.02
	a^*	7.27	7.04	6.93	6.91	6.68	6.97	0.21	0.50
	b^*	8.36	8.44	8.24	8.49	8.36	8.43	0.14	0.83

[1]C = control (no environmental enrichment); P = wooden platform; PB = pecking block; PSB = wooden platform + straw bale; SB = straw bale; SEM = standard error of the mean; T = plastic tunnel.

[a–c]Means lacking a common superscript difference due to the main effect of environmental enrichment ($P < 0.05$).

HCW was not impacted by EE treatment in this study, it is logical that the carcass CY values were also not impacted by treatment. Both were contrary to the hypothesis that EE treatments may increase mobility of turkeys and therefore impact carcass composition.

EE treatment did not impact pH (breast or thigh), DL (breast or thigh), CL, or WBSF ($P > 0.05$), as shown in Table 1. Ultimate pH is one of the primary factors that determines water-holding capacity of muscle proteins and meat products. Although the data showed pH values similar to previous works (Updike et al., 2005; Werner et al., 2008), it was expected to see differences in muscles in pH due to EE treatments providing the possibility of increased physical activity, resulting in shifts in muscle metabolism. The lack of variation in pH indicates that the EE treatments were not impactful enough to alter physical activity to a level sufficient to change muscle pH. Since ultimate pH was not impacted by EE treatment, it is logical that DL and CL, both measurements of retained water, were also not significantly different between EE treatments. Interestingly, WBSF was also not impacted by EE treatment. Since PB turkeys had the heaviest LW, it would be expected for PB turkeys to have the least locomotion, leading to possibly improved tenderness and exhibiting the lowest WBSF values. Since only breast samples were evaluated for CL and WBSF, future work should include thigh WBSF evaluation to see if these locomotive differences are observed.

For fresh meat color, although color values were similar to previous studies (Barbut and Leishman, 2022), EE treatment did not impact breast L^* ($P = 0.78$), a^* ($P = 0.25$), or b^* ($P = 0.94$) or thigh L^* ($P = 0.94$) and a^* ($P = 0.07$), but thigh b^* was impacted (Table 2; $P = 0.04$). It was expected that thigh color was impacted more than breast color due to muscle location. The breast muscle has more of a supportive role compared to the thigh muscle, which is used for locomotion and therefore could be more heavily influenced by differences in physical activity among the EE treatments. PSB thighs displayed the highest b^* values and PB thighs displayed the lowest, meaning that PSB thighs were yellower in color. Other studies have shown comparable results with perching increasing yellowness and redness values of broiler breast meat, potentially due to myoglobin content and/or the increased physical activity of the birds with perches (Fletcher, 2002; Akşit et al., 2017). Therefore, it was anticipated that EE treatment would also impact thigh a^*, but that was not observed in this study. However, thigh a^* was approaching significance ($P = 0.07$), as PBS thighs also displayed the highest a^* values, indicating a redder color. Future studies could investigate the myoglobin content of muscles to confirm color results as well as utilize different storage periods to determine color stability over time.

Processed meat quality traits

The PY, PPL, EML, and texture analyses are found in Table 3, and instrumental color analysis of the processed turkey breasts is found in Table 2. EE treatment impacted EML ($P = 0.04$), had a strong trend toward significance in PY ($P = 0.06$), and did not impact PPL ($P = 0.58$). For EML, PB, PSB, C, and T had the most EML, P had the least EML, and SB had

Table 3. Effect of environmental enrichment on quality parameters of processed turkey breast

	Environmental Enrichment[1]							
Trait[2]	C	P	PB	PSB	SB	T	SEM	*P* Value
PY (%)	83.26	82.86	83.82	83.97	84.08	84.03	0.33	0.06
PPL (%)	1.75	1.80	1.73	1.87	1.70	1.91	0.09	0.58
EML (%)	7.82[a]	7.19[b]	8.06[a]	7.93[a]	7.66[ab]	7.78[a]	0.19	0.04
Hardness (g)	46,138	45,005	45,039	42,085	45,139	42,955	1,126	0.11
Cohesiveness (%)	0.37	0.37	0.37	0.35	0.36	0.35	0.01	0.09
Springiness (%)	63.60	61.20	62.74	62.76	60.50	64.00	1.54	0.57

[1]C = control (no environmental enrichment); P = wooden platform; PB = pecking block; PSB = wooden platform + straw bale; SB = straw bale; SEM = standard error of the mean; T = plastic tunnel.

[2]PY = (final processed weight/initial processed weight) × 100; PPL = ([purge initial weight – purge final weight]/purge initial weight) × 100; EML = ([core initial weight – core final weight]/core initial weight) × 100; hardness = peak force during the first compression of the sample; cohesiveness = area of work during the second compression/area of work during the first compression; springiness = distance of the detected height during the second compression/original compression distance.

[a–c]Means lacking a common superscript difference due to the main effect of environmental enrichment ($P < 0.05$).

intermediate EML. This would indicate the greatest water retention for P; however, this is contrary to the PY findings. PY had a strong trend toward significance, and the results found P to have the lowest PY, indicating a greater loss during thermal processing. It is possible that because P breasts lost the most during processing, there was less moisture to be lost during packaging, and therefore P had less EML.

Instrumental color for processed turkey breast found EE treatment had no effect on a^* ($P = 0.50$) or b^* ($P = 0.83$) but affected L^* values ($P = 0.02$). SB, T, P, and PSB had the greatest L^* values (lighter color values), while C had lower L^* values (darker color values), and PB had intermediate L^* values ($P = 0.02$). However, these findings were unexpected as the fresh breast L^* was not significant and the b^* values were significant. It is possible that the minimal differences observed in the fresh samples were counteracted by the processing ingredients and thermal processing, indicating a poor relationship between fresh color values and processed turkey breast color values. Future research could explore color stability and the impacts of EE treatment on color over time or under different storage conditions.

Finally, the texture profile analysis of the processed turkey breasts showed no differences in hardness ($P = 0.11$), cohesiveness ($P = 0.09$), or springiness ($P = 0.57$), as shown in Table 3. It is logical that texture of the further processed samples was not impacted by EE treatment because ultimate pH, CL, WBSF, and PL were also not impacted by EE treatment, meaning that instrumental texture and water-holding capacity were similar among all EE treatments. Since only breast samples were evaluated for texture profile analysis, future work should include thigh muscle evaluation to see if the results correlate with WBSF results.

Conclusions

This study provided several benchmarks about EE on fresh and processed turkey meat quality. Although some differences were observed for individual quality traits due to EE treatments, the impact of specific EE treatments was not consistent across all meat quality traits. Since this research area is so new, further research needs to be conducted to see if these results change when tested on female or mixed-sex turkey groups as well as different breeds of turkeys. Muscle fiber typing and proximate analysis can be conducted to evaluate specific biochemical or structural differences among the treatment groups. Additionally, further work would need to evaluate these EE treatments in larger commercial facilities in larger-scale operations. Though the differences in this study were limited, it is clear EE treatments did not negatively impact fresh or processed meat quality traits and are still viable methods for producers to improve animal welfare without concerns for end-product quality attributes.

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