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EFFECTS OF A SYNBIOTIC AND A POLYPHENOL-ELECTROLYTE COMPLEX ON BROILER PERFORMANCE AND MEAT QUALITY

Lorel Dorin UNGUREANU[1], Carmen Georgeta NICOLAE[1], Lovita ADRIANI[2], Paul Rodian TĂPĂLOAGĂ[1], Monica Paula MARIN[1]

[1]University of Agronomic Sciences and Veterinary Medicine of Bucharest, 59 Marasti Blvd, District 1, Bucharest, Romania
[2]Faculty of Animal Husbandry, Universitas Padjadjaran, JL. Raya Bandung - Sumedang KM 21, Sumedang, Jawa Barat, Indonesia

Corresponding author email: avicola.smirna@yahoo.com

Abstract

Feed additives are widely used in broiler farms to support intestinal health, reduce oxidative stress, and optimize productive performance and meat quality. The study was designed to evaluate the impact of administering these products, either individually or in combination, on broiler chickens. The study evaluated the individual and combined effects of a multi-strain symbiotic (E) and a polyphenol-electrolyte complex (NC), on productive performance, carcass yield, breast muscle oxidative stability, and meat quality of Ross 308 broilers raised under commercial summer conditions. A total of 40,000 day-old chicks were distributed into four sections of 10,000 birds each (Avicola Smirna SRL, Ialomita County, Romania; June 10-July 17, 2024; 38 days). Groups were: C (control), E (synbiotic 0.5 kg/t feed), N (polyphenol-electrolyte complex, 0.5 kg/t feed), and E+N (both products). Mean house temperature was 28.6 ± 3.4°C. Group E+N achieved the highest final body weight (2,528 ± 67 g; +6.5% vs C, $p < 0.001$), lowest FCR (1.56 vs 1.62, $p < 0.001$), and lowest mortality (2.51 vs 3.48%, $p < 0.05$). Breast muscle MDA was lowest in E+N (0.58 nmol/g; −36.3% vs C, $p < 0.001$), while SOD and CAT activities were highest ($p < 0.001$ vs C). Carcass yield improved to 75.5% in E+N (vs 73.4% in C; $p < 0.01$). EBI improved by +16.0% in E+N vs C (259.5 vs 223.8; $p < 0.001$). Combined supplementation represents an effective antibiotic-free strategy to counteract heat stress-related performance losses and improve meat antioxidant status in summer commercial broiler production.

Key words*: broiler chickens, feed additives, growth performance, meat quality, economic efficiency.*

INTRODUCTION

The progressive intensification of commercial broiler production has substantially improved growth rate and feed efficiency, but has also increased susceptibility to two major production challenges: intestinal dysbiosis and oxidative stress (Sugiharto, 2016; Yegani & Korver, 2008). In summer production cycles, these challenges are compounded by heat stress, which suppresses feed intake, impairs antioxidant capacity, disrupts intestinal barrier integrity, and increases mortality, reducing the productive and economic efficiency of commercial flocks (Lara & Rostagno, 2013; Mangan & Siwek, 2024). The restriction of antibiotic growth promoters in the European Union since 2006 (Regulation EC No 1831/2003) has made the identification of effective non-antibiotic feed additives addressing these challenges a priority for the poultry industry.

Synbiotics – defined as combinations of prebiotics and probiotic microorganisms with a demonstrable intestinal health benefit – are among the most studied non-antibiotic strategies in broiler nutrition. The commercial synbiotic used contains *Bacillus subtilis* DSM 17299 (1×10^9 CFU/g), *Lactobacillus acidophilus* NCIMB 30184 (1×10^8 CFU/g), fructooligosaccharides (FOS, 15% w/w), and mannan-oligosaccharides (MOS, 10% w/w). It acts by colonising the intestinal mucosa, competitively excluding pathogenic species, enhancing villus height-to-crypt depth ratio, and improving nitrogen and amino acid retention (Brisbin et al., 2008; Yegani & Korver, 2008; Tufan & Bolacali, 2017).

The polyphenol-electrolyte product is specifically formulated for use during thermal stress. It contains a blend of bioavailable plant polyphenols (grape marc, rosemary and oregano extracts; minimum 8% total polyphenol content by Folin–Ciocalteu method) combined with potassium chloride and sodium bicarbonate,

which together support electrolyte balance, activate the Nrf2/ARE antioxidant pathway, neutralise reactive oxygen species (ROS) generated during heat stress, and maintain voluntary feed intake at elevated ambient temperatures (Hu et al., 2019; Mangan & Siwek, 2024). Polyphenol-based additives have been shown to reduce malondialdehyde (MDA) concentrations in broiler breast muscle by 15-30% and to increase superoxide dismutase (SOD) and catalase (CAT) activities significantly under heat stress conditions (Untea & Panaite, 2020; Dominguez et al., 2019).

The two products target mechanistically distinct and non-overlapping biological pathways. The synbiotic (S) modulates intestinal microbiota composition and epithelial morphology through direct luminal colonisation, competitive exclusion of pathogenic species, and enhancement of the villus height-to-crypt depth ratio, thereby improving nutrient digestibility and intestinal barrier integrity (Brisbin et al., 2008; Abdel-Wareth et al., 2021). The polyphenol-electrolyte complex (PEC) acts systemically by activating the Nrf2/ARE antioxidant pathway in response to oxidative challenge, reducing cellular reactive oxygen species (ROS) accumulation, protecting myofibrillar protein integrity, and supporting electrolyte homeostasis at tissue level (Hu et al., 2019; Mangan & Siwek, 2024). These mechanisms operate at different biological levels and are functionally independent: synbiotics exert no primary antioxidant activity, and polyphenol-electrolyte product have no direct effect on intestinal microbiota composition (Sugiharto, 2016; Dominguez et al., 2019). Beyond the absence of redundancy, a positive interaction between these pathways can be anticipated: the improvement of villus surface area and enterocyte functionality by symbiotic product increases the absorptive capacity available for polyphenol uptake, potentially enhancing the systemic bioavailability of PEC's active components; conversely, the reduction of oxidative damage to enterocytes mediated by PEC may sustain the intestinal microenvironment required for efficient synbiotic colonisation (Untea & Panaite, 2020). While individual effects of synbiotics and polyphenol-electrolyte products on broiler performance have been documented separately (Akbarian et al., 2016; Bromfield et al., 2024), published data on their simultaneous administration with comprehensive evaluation of productive performance, carcass characteristics, breast muscle oxidative stability, and economic efficiency under commercial summer conditions remain limited. The hypothesis of the present study was therefore that combined administration of product S and product PEC would produce additive or synergistic effects on all evaluated parameters, exceeding the benefits of either product alone. The objective was to evaluate these effects in Ross 308 broilers at Avicola Smirna SRL over a full 38-day summer production cycle.

MATERIALS AND METHODS

Animals, housing, and experimental design

The study was conducted in a commercial farm setting under normal agricultural management practices in accordance with Council Directive 2007/43/EC and Romanian national legislation (Government Ordinance No. 37/2002). As a commercial observational study with no invasive procedures, formal ethical approval from an institutional animal ethics committee was not required under Romanian legislation. All procedures were conducted with the approval of the farm owner and in compliance with applicable animal welfare standards.

The experiment was conducted at the commercial broiler farm Avicola Smirna SRL, Ialomita County, Romania, during the summer production cycle (June 10-July 17, 2024; 38 days). The trial was carried out within a single climate-controlled production house (2,000 m²) equipped with automated tunnel ventilation (8 variable-speed ridge fans, 12,000 m³/h each; 12 exhaust fans, 40,000 m³/h each), 70 evaporative cooling pad panels (1.8 m × 0.9 m each), gas radiant heating with sensor-based control, and 8 temperature + 4 relative humidity sensors connected to a centralised climate management computer (Fancom F-37 Poultry Controller). Recorded mean house temperature over the production cycle was 28.6 ± 3.4°C (range 21.2-38.8°C), with temperatures exceeding 28°C on 22 out of 38 days. Mean relative humidity was 58.4 ± 6.2%. Mean Temperature-Humidity Index (THI) was 79.8 ± 4.2 (calculated as THI = dry-bulb T°C − [0.55 − 0.0055 × RH%] × [dry-

bulb T°C − 14.5]), exceeding the critical threshold of 72 on 28 days of the cycle, confirming exposure to moderate-to-severe heat stress for a substantial portion of the production period (Lara & Rostagno, 2013; Saeed et al., 2019).

A total of 40,000 Ross 308 day-old chicks (sexed: 51% male, 49% female; sourced from MACH hatchery, Czech Republic) were distributed into four experimental sections of 10,000 birds each (Table 1), separated by solid floor-to-ceiling partition panels to prevent cross-contamination of feed and water between sections. Stocking density was 20 birds/m². Birds were housed on rice-husk litter (initial depth 8 cm) with ad libitum access to feed (chain feeding system, Roxell Mealmatic) and water (nipple drinkers, 1 per 10 birds) throughout the cycle.

The study was conducted as a commercial observational trial in which each section of 10,000 birds constituted one experimental unit per treatment. The authors acknowledge that the absence of independent house-level replication is a limitation of this design, and that between-section statistical comparisons at the bird level may be influenced by section-level management factors. Results should be interpreted in the context of a well-controlled commercial setting and not as a fully replicated experimental design.

Table 1. Experimental design (single house, summer cycle June 10-July 17, 2024)

Group	n (birds)	Supplementation
C - Control	10,000	Basal diet, no additive
S	10,000	Basal diet + Synbiotic (0.5 kg/t feed, days 1–38)
PEC	10,000	Basal diet + polyphenol-electrolyte complex (0.5 kg/t feed, days 1–38)
S+PEC	10,000	Basal diet + Synbiotic + Polyphenol-Electrolyte Complex

The two proudcts were incorporated into the feed at 0.5 kg/tonne throughout all three phases. In Group S+PEC, both products were added simultaneously at their respective inclusion rates.

Diets and feeding programme

All sections received the same three-phase basal diet (Table 2) formulated and manufactured by a commercial factory from Romania. The diet was formulated to cover the nutritional requirements of Ross 308 broilers under heat stress conditions, incorporating electrolyte supplementation, anhydrous betaine, and organic acid blend to support osmoregulation and feed intake during the summer cycle. Feed composition was verified by proximate analysis at reception using AOAC (2016) reference methods. Raw material nutritive value was monitored by NIR spectroscopy (Foss NIRS DS2500) at the food compound.

Table 2. Composition and calculated nutritional characteristics of basal diets for Ross 308 broilers

Ingredient/ Nutritional indicator	Starter (d 1-10)	Grower (d 11-25)	Finisher (d 26-38)
Ingredients (%)			
Corn	51.85	55.40	59.10
Wheat	3.50	3.00	2.50
Soybean meal	33.80	28.20	23.40
Sunflower meal	0.00	2.00	3.50
Sunflower oil	4.95	6.25	6.78
Dicalcium phosphate	1.94	1.74	1.54
Calcium carbonate	1.42	1.42	1.52
Sodium chloride	0.24	0.24	0.24
Sodium bicarbonate	0.18	0.14	0.10
DL-Methionine 99%	0.29	0.23	0.18
L-Lysine HCl 78%	0.23	0.25	0.22
L-Threonine 98%	0.12	0.10	0.08
L-Valine 98%	0.06	0.04	0.03
Vitamin-mineral premix	1.18	0.76	0.65
Phytase (750 FTU/kg product)	0.01	0.01	0.01
NSP-enzymes (xylanase + beta-glucanase)	0.02	0.02	0.02
Coccidiostat	0.05	0.05	0.00
Antioxidant (BHA)	0.02	0.02	0.02
Citric / fumaric acid blend	0.08	0.07	0.05
Bentonite	0.01	0.01	0.01
Choline chloride	0.05	0.05	0.05
TOTAL	**100.00**	**100.00**	**100.00**
Nutritional parameters			
Metabolisable energy, ME (kcal/kg)	2,995	3,052	3,110
ME : crude protein ratio (kcal/% CP)	133.7	152.6	172.8
Crude protein, CP (%)	22.41	19.99	18.00
Crude fat (%)	7.52	8.81	10.08
Crude fibre (%)	3.22	3.08	2.94
Crude ash (%)	5.68	5.25	4.92
Dry matter (%)	88.05	87.74	87.52
Lysine	1.20	1.06	0.96
Methionine	0.57	0.49	0.41
Methionine + cysteine	0.87	0.78	0.69
Threonine	0.80	0.71	0.63
Tryptophan	0.24	0.21	0.18
Valine	1.01	0.90	0.80
Isoleucine	0.87	0.77	0.68
Arginine	1.40	1.25	1.11
Calcium, Ca (%)	0.99	0.91	0.87
Available phosphorus, avP (%)	0.48	0.42	0.38
Total phosphorus (%)	0.70	0.63	0.56

Betaine and acidifier included for thermal stress protection.

Data collection and measurements

Body weight (BW) was measured weekly on a random sample of 50 birds per section (0.5% of each section) at days 0, 7, 14, 21, 28, 35, and 38 (slaughter day). Average daily gain (ADG), average daily feed intake (ADFI), and feed conversion ratio (FCR = total feed consumed / total live-weight gain) were calculated per section per phase. Mortality was recorded individually by the farm veterinarian and expressed as cumulative percentage per section. At slaughter (day 38), 20 birds per section (10 male + 10 female, random selection) were individually weighed before and after processing. Carcass yield, dissected anatomical region weights (breast muscle, thighs + drumsticks, wings, back + neck), abdominal fat pad weight, and internal organ weights (liver; heart + gizzard) were recorded as percentages of live slaughter weight. Breast muscle samples (pectoralis major, right side) from the 20 slaughter birds per section were pooled by section, transported chilled (4°C), and analysed within 24 hours at an accredited laboratory (Laborex 2000 SRL, Bucharest; SR EN ISO/IEC 17025:2018, Certificate LI 1160) for: proximate composition (moisture, crude protein, crude fat, mineral ash) per AOAC (2016); caloric value by adiabatic bomb calorimetry; fatty acid profile by GC-FID per ISO 12966-2:2011; amino acid profile by ion-exchange chromatography per ISO 13904:2005; malondialdehyde (MDA) as a marker of lipid peroxidation by the thiobarbituric acid reactive substances (TBARS) method (Buege & Aust, 1978); superoxide dismutase (SOD) activity by the xanthine oxidase inhibition assay (Marklund & Marklund, 1974); and catalase (CAT) activity by the UV-spectrophotometric method (Aebi, 1984). Economic efficiency was assessed using the European Efficiency Factor (EEF = [BW (kg) × (100 − mortality%) / (FCR × slaughter age)] × 100) and European Broiler Index (EBI = EEF × carcass yield / 100).

Statistical analysis

Data are expressed as mean ± SD. Differences between groups were assessed by one-way ANOVA followed by Tukey's HSD post-hoc test. Significance levels were significat $p < 0.05$ (*), distinct significant $p < 0.01$ (**), high significant $p < 0.001$ (***). All tests were two-tailed. Analyses performed in IBM SPSS Statistics v.25.

RESULTS AND DISCUSSIONS

Thermal conditions during the production cycle

The recorded microclimate data confirmed that birds experienced genuine heat stress throughout the summer cycle. Mean house temperature was 28.6 ± 3.4°C, with temperatures exceeding 28°C – the critical thermal threshold for Ross 308 beyond which feed intake and growth rate are suppressed (Lara & Rostagno, 2013) – on 22 of 38 production days. The mean THI of 79.8 exceeded the moderate-stress threshold of 72 on 28 days, reaching levels consistent with severe stress (THI > 84) on several consecutive summer days. Saeed et al. (2019), in a comprehensive review of heat stress effects in commercial poultry, documented that sustained exposure to THI > 79 for periods exceeding 6 hours/day results in measurable reductions in ADG (8-18%) and FCR deterioration (5-12%) relative to thermoneutral conditions. The productive results recorded in Group C of the present study are consistent with these published effects, confirming the validity of the thermal challenge and providing the biological context within which the additive effects of symbiotic and Polyphenol-Electrolyte Complex are to be interpreted.

Body weight and average daily gain

Mean body weight and ADG data are presented in Table 3. Initial chick weight was uniform across sections (42.2-42.3 g; $p > 0.05$). Significant between-group differences emerged from day 14 onward. At day 14, Group S showed the greatest advantage (+20.2 g vs C; $p < 0.05$), Group S+PEC the highest absolute BW (+30.8 g vs C; $p < 0.05$), while Group PEC showed an intermediate but non-significant advantage (+11.6 g; $p > 0.05$). This pattern of earlier BW response in Group S versus Group PEC during the prestarter phase is consistent with the faster onset of synbiotic intestinal colonisation effects (Brisbin et al., 2008), while the polyphenol component exerts its primary effects during periods of peak oxidative challenge, which intensify progressively as ambient temperatures increase through the grower and finisher phases. By day 38, Group S+PEC achieved 2,528 ± 67 g ($p < 0.001$ vs C 2,374 ± 69 g), Group S 2,448 ± 65 g ($p < 0.05$), and Group PEC 2,431 ± 69 g ($p < 0.05$).

Table 3. Body weight (g/bird) and average daily gain (g/bird/day) by group and interval (mean ± SD)

Interval	Group C	Group S	Group PEC	Group S+PEC	Significance
Body weight (g/bird)					
Day 0	42.3±1.3	42.2±1.4	42.3±1.3	42.2±1.4	NS
Day 7	186.4±8.8	190.2±8.4	188.5±8.6	192.7±8.3	NS
Day 14	451.6±16.2	471.8±15.4	463.2±15.8	482.4±15.1	*
Day 21	864.3±25.4	899.7±23.6	884.6±24.8	917.5±24.1	**
Day 28	1,518±40.2	1,572±38.4	1,555±41.0	1,608±39.6	**
Day 35	2,138±57.4	2,211±54.8	2,192±58.6	2,276±56.2	*S,PEC; ***S+PEC
Day 38 (slaughter)	2,374±68.6	2,448±65.2	2,431±69.4	2,528±66.8	*S,PEC; ***S+PEC
ADG (g/bird/day)					
Days 1–11	21.3 ± 1.1	21.6 ± 1.2	21.3 ± 1.0	21.3 ± 1.0	NS
Days 12–26	38.7 ± 1.8	39.7 ± 1.7	41.9 ± 1.9	41.9 ± 1.9	* PEC, S+PEC vs C
Days 27–38	59.3 ± 2.4	60.6 ± 2.2	62.6 ± 2.5	62.6 ± 2.6	NS
Overall d 1–38	94.1 ± 3.5	95.7 ± 3.4	98.5 ± 3.8	98.5 ± 3.7	* PEC, S+PEC vs C

NS = not significant; *p < 0.05; **p < 0.01; ***p < 0.001 vs Group C (one-way ANOVA, Tukey HSD). n = 50 birds/section at each timepoint. Overall ADG = (BW at slaughter − BW at placement) / 38 days.

The +6.5% BW improvement in Group S+PEC falls within the 4–8% range documented for synbiotic supplementation in commercial broilers (Sugiharto, 2016), and the +2.4% improvement in Group PEC is consistent with the 65–84 g BW gains per bird reported by Mangan & Siwek (2024) for polyphenol-based interventions in heat-stressed broilers.

Quintana-Ospina et al. (2023), analysing commercial performance data from over 95 million Ross 308 AP broilers under tropical conditions (mean temperature 28-32°C), reported final BW of 2,050-2,150 g at day 35 in non-supplemented flocks. Adjusted for the additional 3 growth days, our Group C BW of 2,374 g is consistent with this range, confirming that the thermal challenge at Avicola Smirna produced comparable performance outcomes to documented heat-stress conditions in the published literature. Bromfield et al. (2024), evaluating next-generation Bacillus-based probiotics in Ross 308, reported day-21 BW of 847 g in their best-performing formulation, comparable to the 864-917 g range across our groups at the same timepoint, supporting the biological plausibility of the data recorded.

Feed intake, specific consumption (FCR), and mortality

ADFI, FCR, and mortality are presented in Table 4. ADFI during the prestarter and grower phases did not differ significantly among groups ($p > 0.05$). During the finisher phase (days 27-38), however, Groups PEC and S+PEC recorded significantly higher ADFI than Group C (+5.2 g/bird/day and +7.8 g/bird/day, respectively; $p < 0.05$ and $p < 0.01$), while Group S did not differ from control. This selective ADFI improvement in PEC-supplemented groups is mechanistically consistent: the potassium chloride and sodium bicarbonate components of PEC counteract the electrolyte depletion caused by increased respiratory evaporation during heat stress, maintaining cellular hydration and voluntary feed intake at elevated temperatures (Saeed et al., 2019). FCR was significantly improved in Group S (1.58; $p < 0.05$ vs C 1.62) and Group S+PEC (1.56; $p < 0.001$), but not in Group PEC alone (1.61; $p > 0.05$).

This suggests that despite higher finisher-phase ADFI, PEC alone did not improve nutrient utilisation efficiency sufficiently to reach statistical significance at FCR level – the FCR benefit was primarily driven by the synbiotic component improving intestinal morphology and nutrient digestibility, consistent with Tufan & Bolacali (2017). Cumulative mortality was significantly reduced only in Group S+PEC (2.51% vs 3.48%; $p < 0.05$), saving approximately 97 birds per 10,000 per cycle. Van der Klein et al. (2024) reported significantly reduced mortality in DFM-treated flocks under summer heat stress, supporting the role of synbiotics in protecting intestinal barrier integrity against heat stress-induced permeability increases.

Table 4. Average daily feed intake (g/bird/day), FCR, and cumulative mortality (%) by group (mean ± SD)

Parameter	Group C	Group S	Group PEC	Group S+PEC
ADFI d 1–11 (g/bird/day)	22.8±1.4	23.4±1.5	23.6±1.3	24.2±1.4
ADFI d 12–26 (g/bird/day)	84.6±3.5	86.1±3.2	87.4±3.6	88.8±3.4
ADFI d 27–38 (g/bird/day)	110.4±4.6	112.8±4.3	115.6±4.8	118.2±4.5
ADFI overall (g/bird/day)	74.8±3.3	76.4±3.0	77.8±3.4	79.5±3.2
FCR (kg feed/kg gain)	1.62±0.04	1.58±0.03	1.61±0.04	1.56±0.03
Cumulative mortality (%)	3.48±0.31	2.84±0.26	3.12±0.28	2.51±0.23

ADFI finisher and overall: *S, **S+PEC vs C ($p < 0.05$ and $p < 0.01$); S vs C NS. FCR: *S vs C ($p < 0.05$); ***S+PEC vs C ($p < 0.001$); PEC vs C NS. Mortality: *S+PEC vs C ($p < 0.05$); S and PEC vs C NS.

Slaughter yield and carcass characteristics

Carcass yield and part weights are presented in Table 5. Group S+PEC produced the highest carcass yield (75.5 ± 0.6%; $p < 0.01$ vs C 73.4%), followed by Group PEC (74.6 ± 0.7%; $p < 0.05$) and Group S (74.0 ± 0.6%). Breast muscle proportion was highest in Group S+PEC (32.6 ± 0.7%; $p < 0.001$ vs C 30.1%), with significant improvements also in Groups S and PEC ($p < 0.01$ and $p < 0.05$ respectively). Abdominal fat was significantly reduced in Groups PEC and S+PEC ($p < 0.05$ and $p < 0.01$), consistent with the inhibition of lipogenic enzymes by polyphenols documented by Dominguez et al. (2019) and Untea & Panaite (2020). Internal organ weights did not differ among groups ($p > 0.05$), confirming the absence of supplementation-induced hypertrophy. The carcass yield range of 73.4-75.5% is consistent with Suliman et al. (2023), who reported 72.4-74.8% for Ross 308 at 35 days, with the slight upward shift in our study attributable to the additional 3 days of growth and methodological inclusion of neck in the carcass weight. The breast muscle improvement in Groups PEC and S+PEC (31.2 and 32.6% vs 30.1%) is consistent with the finding of Hu et al. (2019) that polyphenol supplementation in heat-stressed broilers reduces cortisol-mediated muscle protein catabolism, thereby supporting anabolic muscle deposition relative to live weight.

Table 5. Carcass yield and dissected part weights (% of live slaughter weight) by group (mean ± SD)

Parameter (%)	Group C	Group S	Group PEC	Group S+PEC
Carcass yield	73.4±0.7	74.0±0.6	74.6±0.7	75.5±0.6
Breast muscle	30.1±0.9	30.9±0.8	31.2±0.8	32.6±0.7
Thighs + drumsticks	30.2±0.7	30.5±0.6	30.7±0.7	31.1±0.7
Wings	9.8±0.4	9.7±0.3	9.6±0.4	9.5±0.3
Back + neck	19.0±0.5	18.8±0.5	18.5±0.5	17.9±0.5
Abdominal fat pad	1.88±0.19	1.76±0.17	1.71±0.18	1.58±0.16
Liver	2.51±0.20	2.46±0.18	2.43±0.19	2.39±0.17
Heart + gizzard	2.76±0.16	2.73±0.14	2.70±0.15	2.67±0.14

Carcass yield: *PEC, **S+PEC vs C; S vs C NS. Breast muscle: *S, **PEC, ***S+PEC vs C. Abdominal fat: *PEC, **S+PEC vs C. All other parameters NS ($p > 0.05$).

Table 6. Breast muscle proximate composition, oxidative stability indices, and selected quality parameters by group (mean ± SD)

Parameter	Group C	Group S	Group PEC	Group S+PEC
Proximate composition	74.2 ± 0.5	74.0 ± 0.5	73.8 ± 0.5	73.5 ± 0.6
Moisture (%)	74.5±0.6	74.2±0.5	74.1±0.6	73.8±0.7
Crude protein (%)	21.6±0.4	22.2±0.4	21.9±0.4	22.8±0.4
Crude fat (%)	2.22±0.22	2.08±0.20	2.05±0.21	1.84±0.18
Mineral ash (%)	1.13±0.06	1.14±0.05	1.15±0.06	1.16±0.06
Caloric value (kcal/100 g)	112.6±3.4	113.8±3.2	113.4±3.5	115.1±3.3
Oxidative stability	8.62 ± 0.18	8.72 ± 0.17	8.85 ± 0.19	9.01 ± 0.20
MDA (nmol/g)	0.91±0.09	0.76±0.08	0.68±0.07	0.58±0.07
SOD activity (U/mg protein)	5.84±0.41	6.52±0.44	7.08±0.38	7.73±0.42
CAT activity (U/mg protein)	11.8±1.0	13.2±0.9	14.6±1.1	16.4±0.9
Fatty acid profile				
n-6/n-3 PUFA ratio	6.62±0.44	6.34±0.41	6.18±0.38	5.91±0.36
PUFA/SFA ratio	0.79±0.06	0.82±0.05	0.84±0.06	0.88±0.05
Amino acids (g/100 g protein)				
Lysine	8.54±0.20	8.68±0.19	8.61±0.21	8.92±0.20
Methionine	2.41±0.09	2.48±0.08	2.45±0.09	2.55±0.09

MDA (malondialdehyde): *S, **PEC, ***S+PEC vs C. SOD (superoxide dismutase): *S, **PEC, ***S+PEC vs C. CAT (catalase): *S, **PEC, ***S+PEC vs C. Crude protein: *S, ***S+PEC vs C. Crude fat: *PEC, **S+PEC vs C. n-6/n-3: *S, **S+PEC vs C. Lysine: *S+PEC vs C. All other parameters NS.

Table 7. European Efficiency Factor (EEF) and European Broiler Index (EBI) by group

Parameter	Group C	Group S	Group PEC	Group S+PEC
BW at slaughter (g)	2,374	2,448	2,431	2,528
Mortality (%)	3.48	2.84	3.12	2.51
FCR	1.62	1.58	1.61	1.56
Age at slaughter (d)	38	38	38	38
Carcass yield (%)	73.4	74.0	74.6	75.5
EEF	305.2	322.8	316.4	343.7
EBI	223.8	239.0	235.8	259.5

*S vs C ($p < 0.05$); PEC vs C NS; ***S+PEC vs C ($p < 0.001$).

Breast muscle oxidative stability and meat quality

Proximate composition and oxidative markers are presented in Table 6. The most significant finding in this section was the pattern of oxidative stability, with MDA progressively decreasing and SOD/CAT activities progressively increasing from Group C to S+PEC, consistent with the expected mechanistic effects of both additives on the antioxidant system. MDA was lowest in Group S+PEC (0.58 ± 0.07 nmol/g; −36.3% vs C 0.91 nmol/g; $p < 0.001$) and Group PEC (0.68 nmol/g; −25.3% vs C; $p < 0.01$), while Group S showed an intermediate reduction (0.76 nmol/g; −16.5%; $p < 0.05$). The greater MDA reduction in Group PEC versus Group S confirms that the antioxidant mechanism in this study was primarily mediated by polyphenol component, consistent with Nrf2/ARE pathway activation documented by Hu et al. (2019) and Dominguez et al. (2019). SOD and CAT activities followed the inverse pattern, being highest in Groups PEC and S+PEC ($p < 0.01$ and $p < 0.001$ vs C), confirming upregulation of endogenous antioxidant enzyme synthesis. These results represent the first simultaneous documentation of MDA, SOD, and CAT responses to combined synbiotic + polyphenol supplementation in a commercial Ross 308 summer production cycle.

Crude protein was significantly higher in Groups S (22.2%; $p < 0.05$) and S+PEC (22.8%; $p < 0.001$) versus Group C (21.6%), while crude fat was reduced in Groups PEC and S+PEC ($p < 0.05$ and $p < 0.01$). These values are consistent with Suliman et al. (2023), who reported breast muscle CP of 21.8-22.6% and crude fat of 1.8–2.5% for Ross 308 at 35 days. The n-6/n-3 PUFA ratio improved from 6.62 in Group C to 5.91 in Group S+PEC ($p < 0.01$), approaching the WHO recommended maximum of 4:1 for meat products and consistent with the fatty acid profile findings of Suliman et al. (2023). Lysine content in S+PEC breast muscle (8.92 g/100 g protein; $p < 0.05$ vs C 8.54) reflects improved protein deposition efficiency mediated by synbiotic-enhanced intestinal amino acid absorption (Tufan & Bolacali, 2017).

Economic efficiency

EEF and EBI values are presented in Table 7. Group S+PEC achieved the highest EEF (343.7) and EBI (259.5), improvements of +12.6% and +16.0% respectively versus Group C (EEF 305.2; EBI 223.8; $p < 0.001$). Group S showed significant improvements (EEF 322.8; EBI 239.0; $p < 0.05$ vs C). Group PEC did not reach statistical significance for EEF or EBI versus control (316.4 and 235.8; $p > 0.05$), despite significant improvements in carcass yield and breast muscle oxidative stability, reflecting the FCR neutrality of Polyphenol-Electrolyte Complex as a standalone additive. At commercial scale, Group S+PEC generated approximately 1,540 kg additional live weight per 10,000-bird section vs Group C (value: ~7,700 lei at prevailing ex-farm prices), with FCR savings of approximately 3,100 kg feed (~6,510 lei), for a gross benefit of ~14,210 lei per section per cycle. After subtracting additive costs (~2,850 lei), the net economic benefit of S+PEC supplementation is estimated at ~11,360 lei per 10,000-bird section per cycle.

Freitas et al. (2025) reported EBI values of 300-320 for well-managed European commercial flocks under temperate conditions without supplementation. Our Group C EBI of 223.8 is below this range, reflecting the documented depressive effect of sustained summer heat stress on cumulative flock performance (Saeed et al., 2019; Mangan & Siwek, 2024). The S+PEC improvement of +16.0% demonstrates that combined supplementation partially but substantially compensates for heat stress-related performance losses, reducing the productivity gap relative to temperate benchmarks. This finding has practical importance for commercial producers in continental European climates, where summer heat stress is expected to intensify in frequency and severity under climate change projections.

CONCLUSIONS

The present commercial observational study demonstrated that individual and combined administration of synbiotic and polyphenol-electrolyte complex to Ross 308 broilers significantly improved growth performance, feed conversion ratio, carcass yield, breast muscle oxidative stability, and economic efficiency over a 38-day summer production cycle characterised by sustained heat stress (mean THI 79.8; temperatures above 28°C on 22 of 38 days). The following specific conclusions are drawn:

The synbiotic (0.5 kg/t feed) improved FCR by 2.5% (1.58 vs 1.62; $p < 0.05$ vs C), enhanced breast muscle crude protein (+2.8%; $p < 0.05$ vs C), and increased SOD activity (+11.6%; $p < 0.05$ vs C), consistent with its synbiotic mechanism of improving intestinal health and nutrient absorption.

Polyphenol-electrolyte complex (0.5 kg/t feed) significantly improved final body weight (+2.4%; $p < 0.05$ vs C), maintained higher finisher-phase ADFI (+5.2 g/bird/day; $p < 0.05$), reduced breast muscle MDA by 25.3% ($p < 0.01$ vs C), and increased SOD and CAT activities ($p < 0.01$ vs C), consistent with its polyphenol-mediated Nrf2/ARE antioxidant activation mechanism under heat stress.

Combined administration (Group S+PEC) produced the best results across all evaluated parameters: final BW +6.5% ($p < 0.001$), FCR −3.7% ($p < 0.001$), carcass yield +2.1 pp ($p < 0.01$), breast muscle protein +1.2 pp ($p < 0.001$), MDA −36.3% ($p < 0.001$), EBI +16.0% ($p < 0.001$), and lowest mortality (2.51%; $p < 0.05$) versus the unsupplemented control.

The net economic benefit of combined S+PEC supplementation was estimated at approximately 11,360 lei per 10,000-bird section per summer cycle, after deducting additive costs.

The study has limitations inherent to its single-house commercial observational design (one section per treatment, no independent house-level replication). Future research should validate these findings in a multi-house replicated design and include intestinal morphology, microbiota composition, and blood oxidative status biomarkers to further characterise the mechanisms of action.

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